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FROM

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BULLETIN No. 199

GERM CONTENT OF MILK
I. AS INFLUENCED BY THE FACTORS AT THE BARN

By M. J. PRUCHA and H. M. WEETER

URBANA, ILLINOIS, MAY, 1917

The Station

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FOREWORD

The public desire and should be able to obtain a supply of satisfactorily clean and wholesome milk. The representatives of the consuming public in this matter, the health officials, have frequently adopted the germ content of milk as an index of cleanliness and wholesomeness. In this way, the legal limit of germ life permissible in the milk supply as shown by the plate count has been placed in Champaign-Urbana at 100,000 per cubic centimeter and in St. Louis at 5,000,000 per cubic centimeter.

No matter what is our personal judgment regarding the wisdom of such bacterial standards, the legally constituted authorities having thus established these limits of bacterial content, the burden rests upon the producer and the retailer to observe them. When adjusting their business methods to such variable limits as those mentioned above, it is important that the dairymen have fairly accurate knowledge of the relative importance of the various dairy operations upon the germ content of the milk.

In the general directions which the health officials have formulated for the guidance of the dairymen, great stress has been laid upon the construction and condition of the cow stable. Accordingly, technical studies of the influence of dairy factors naturally included a measurement of the influence of barn conditions. The results obtained at the New York Agricultural Experiment Station from such technical studies of the influence of barn conditions were so out of keeping with the ideas of the health officials that it seemed best to redetermine independently this relationship at this experiment station.

The surprisingly accordant results which have been obtained at these two experiment stations should not be understood as countenancing dirty methods or dirty milk. They merely point out that earlier impressions, formed in the absence of exact data, did not give a correct value to the importance of barn conditions in connection with germs in milk.

Neither should these results be taken as a criticism of health officials. Such officers are charged with the protection of the public health. Where the facts are available, they utilize them. Where exact information is lacking, they must proceed in accordance with their best judgment even tho they recognize the fallibility of such judgment.

The slight effect of barn conditions upon the number of germs in milk was clearly brought out by the extended studies at the New

York Agricultural Experiment Station. The studies here reported were made in a different part of the country, in three quite dissimilar barns, by a different laboratory force, using a different method of attacking the problem. The results of this latter study are quite in accord with those obtained in New York.

The earlier misconceptions of health officials regarding the importance of barn conditions resulted in placing unjust economic burdens upon the producer. Now that more accurate data upon this question is available it is to be hoped that these burdens will be more fairly distributed.

H. A. Harding
Chief in Dairy Husbandry

GERM CONTENT OF MILK

I. AS INFLUENCED BY THE FACTORS AT THE BARN

By M. J. PRUCHA, Assistant Chief in Dairy Bacteriology, and
H. M. Weeter, Assistant in Dairy Husbandry

INTRODUCTION

The studies on which this bulletin is based are a part of an investigation begun by H. A. Harding in 1906 at the New York (Geneva) Agricultural Experiment Station. In an introduction to Bulletin 365 of that institution Dr. Harding makes the following statement as to the purpose of the investigation: "When health officials, failing to find other means of characterizing sanitary milk, undertook to specify the conditions under which it should be produced, they were confronted by an almost total lack of detailed information upon this subject. This lack arose from the fact that available studies upon milk sanitation were in the nature of general surveys of the situation. While these general surveys were a necessary preliminary, they gave little information as to either the absolute or the relative importance of any given dairy operation. . . . . The importance of the interests involved demands that the needed information shall be furnished as promptly as possible."

Investigations toward this end have been carried on at the New York Agricultural Experiment Station since 1906.[1] The aim in these investigations has been to separate the various sources of contamination to which milk is subject and to measure the influence of each on the germ content of milk. The results from these studies point to the conclusion that barn conditions and barn operations have only a small influence upon the germ content of milk.

If the above conclusion is true, it will radically change our conception concerning the relative importance of the different sources of milk contamination. Since it is an axiom in scientific work that no important results are accepted until they have been verified independently by other workers, it was decided to repeat the study made at the New York Station upon the influence of barn conditions and operations on the germ content of milk. Accordingly, the subject has been restudied at the Illinois Station by a new force of workers, in a new laboratory, and in three barns of distinctly different types. The method of attack in the present study differed from the method used at the New York Station in that all the barn factors were grouped together and their collective influence on the germ content of the milk was determined. In these, as in the previous studies, the utensils were considered as a separate source of contamination and were therefore thoroly steamed before each milking.[1]

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[1] Harding, H. A., Wilson, J. K., and Smith, G. A. Milking Machine: Effect of Methods of Handling on the Germ Content of Milk. N. Y. (Geneva) Agr. Exp. Sta. Bul. 317. 1909.

Harding, H. A., and Wilson, J. K. The Modern Milk Pail. N. Y. (Geneva) Agr. Exp. Sta. Bul. 326, pp. 248-281. 1910.

Harding, H. A., Ruehle, G. L., Wilson, J. K., and Smith, G. A. The Effect of Certain Dairy Operations upon the Germ Content of Milk. N. Y. (Geneva) Agr. Exp. Sta. Bul. 365, pp. 198-233. 1913.

Harding, H. A., and Wilson, J. K. A Study of the Udder Flora of Cows. N. Y. (Geneva) Agr. Exp. Sta. Tech. Bul. 27. 1913.

Ruehle, G. L. A., and Kulp, W. L. Germ Content of Stable Air and Its Effect upon the Germ Content of Milk. N. Y. (Geneva) Agr. Exp. Sta. Bul. 409, pp. 418-474. 1915.

THE THREE BARNS IN WHICH THE STUDY WAS MADE AND THE DAIRY METHODS EMPLOYED IN EACH

In order that the results of this study may be thoroly understood and their significance fully appreciated, it is necessary to give a somewhat full description of the conditions and the dairy operations in each of the three barns in which the experiment was conducted.

Barn I is a two-story frame building 75 feet long and 45 feet wide. There are approximately 900 cubic feet of space and 9 square feet of window glass per cow. Two rows of iron stalls facing the central aisle and running lengthwise accommodate forty cows. The length of the floor from the manger to the gutter is 5 feet 5 inches in one row of stalls and 5 feet in the other row. The iron stalls used in this barn are known as "Drown" stalls, and are so constructed that it is possible, to a certain extent, to adjust the space inside the stall to the size of the animal.

The ceiling and the walls are constructed of matched lumber, are painted, and are without any large crevices. The floor, the gutters, and the mangers are of cement. The feeding materials are stored in a separate part of the building and are brought into the barn thru an end door.

During the investigation, the milkings began at five in the morning and at four in the afternoon and lasted an hour and a half. After the morning milking, the cows were turned out into a yard, the manure was taken out, the floors were flushed with water, and the stalls were bedded with sawdust. When feasible, the manure was placed directly on the wagon and taken away. At other times it was dumped about thirty-five feet from the barn in a yard to which the cows did not have access. A tight board fence, six feet high, separated this manure pile from the barn.

After the barn had been cleaned, the cows were brought back, fed hay, and cleaned. The amount of time spent on the cleaning of the cows was approximately five minutes to each animal. Occasionally the cows were used for demonstration purposes before classes, and for such occasions their udders and flanks were clipped. This clipping, however, was not practiced regularly for the purpose of reducing the number of bacteria in the milk. Likewise, during the experiment, no systematic attempt was made to clean the cows before each milking. If any of them became dirty prior to the milking, the milker wiped the loose dirt from their flanks and udders with a handful of the sawdust bedding. In 1914 the udders of the cows were wiped with a damp cloth previous to the milkings, but in 1915 this practice was discontinued intentionally.

---

[1] The influence of dairy utensils upon the germ content of milk has been studied separately and the results will be reported later.

During the milking the cows were fed silage and grain. The hay was brought into the barn usually before the milking was finished, and was distributed into the mangers. This operation frequently caused a considerable amount of dust in the air. The milkers wore milking suits which were changed twice each week.

Barn II is a two-story, circular building 70 feet in diameter. There are about 800 cubic feet of space and 9 square feet of window glass per animal. The platform upon which the cows are stanchioned is circular, running around a central ring 45 feet in diameter. Around the outer edge of this platform is the gutter, and between the gutter and the outside brick wall runs a passageway about six feet in width.

Especial effort was made in constructing this barn to so equip it that the cows would be prevented from lying down in their own feces.

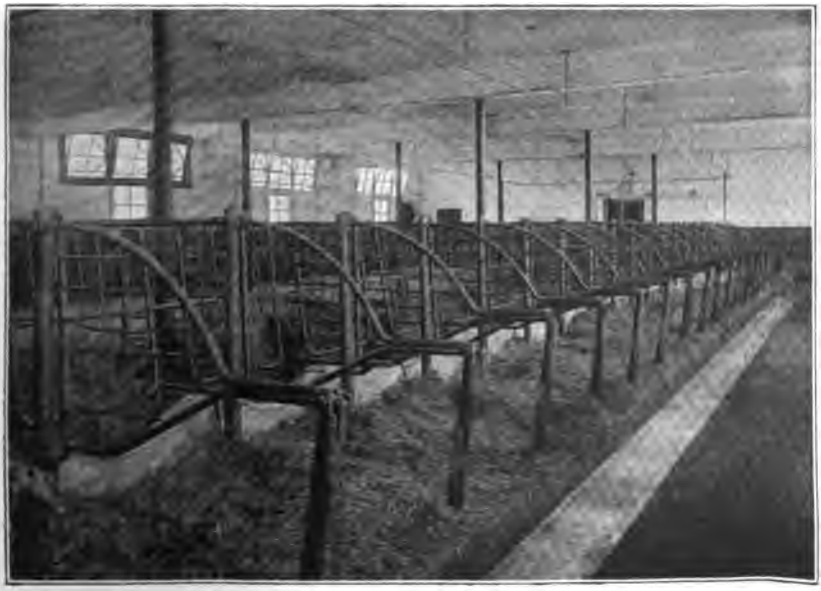

FIG. 1.—THE INTERIOR OF DAIRY BARN I

This was accomplished by varying the width of the platform upon which the cows are stanchioned and by installing adjustable stanchions. By these two means the space for each cow can be adjusted as desired.

The brick wall and the wooden ceiling are free from any large crevices, but are rough and not painted. The platform upon which the cows are stanchioned is paved half way around with cork bricks and the other half with creosote blocks. In the center of the barn is a silo 16 feet in diameter and the chutes for the grain and the hay which are stored on the second floor.

With few exceptions the daily operations in this barn were about the same as in Barn I. The floor was cleaned regularly, but as a rule was not flushed with water. In cleaning the cows, only about one minute of labor a day was allowed for each animal, while in Barn I a period of five minutes was devoted to that purpose. This reduction in labor in keeping the cows clean was brought about by carefully adjusting to their size the spaces in which the cows were stanchioned. During milking and feeding and in unfavorable weather the cows were stanchioned in the barn; at other times they were turned out into an acre dry-lot adjacent to the barn.

Barn III is a two-story, round, basement barn 50 feet in diameter. Only ten cows occupied it during this experiment, each animal having approximately 1,500 cubic feet of space and 15 square feet of window glass. In the center of the barn are the silo and the grain and the hay chutes. Around these is a circular passageway 10 feet in width. On the outer edge of this passageway are the mangers and the stanchions, both constructed of wood. There is only a dirt floor and there are no gutters. The brick side-walls and the wooden ceiling are tight but are not painted. During the experiment the cobwebs and the dust were abundant, not having been cleaned from the ceiling for four years previous.

The cows were stanchioned only during the milkings. Between milkings they were allowed to roam about in the barn and in the quarter-acre dry-lot adjacent to the barn. A large door leading from the barn into the dry-lot was always open. The floor in the barn was covered with straw once a day, but the manure was allowed to accumulate on the floor and was removed from the barn only twice a year. The cows were not kept as clean as in Barns I and II, but no manure was allowed to accumulate and to cake on their flanks and udders.

These three barns in a general way represent three classes of dairy barns, Barn I being in excellent condition, Barn II being good, and Barn III poor. The difference between Barn I and Barn II as to cleanliness, however, was not very great. On the other hand, Barn III would be classed as a dirty barn, and it is doubtful whether the milk from it would be admitted to the market of some cities. A photograph of each of the three barns is shown in Figs. 1, 2, and 3.

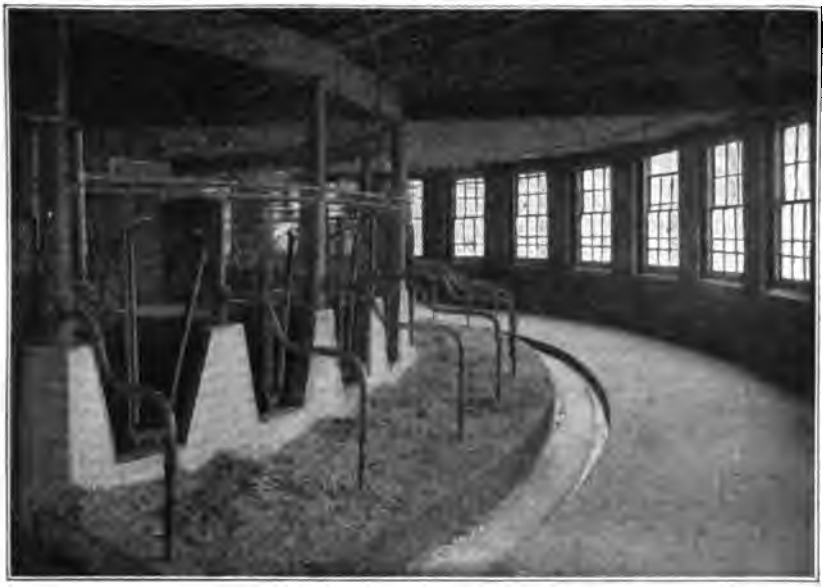

FIG. 2.—THE INTERIOR OF DAIRY BARN II

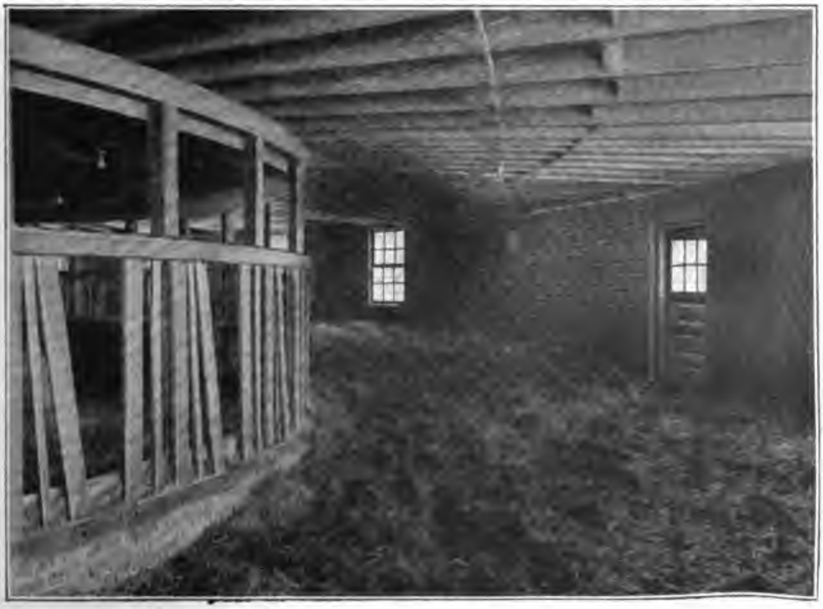

FIG. 3.—THE INTERIOR OF DAIRY BARN III

METHODS OF STUDY

Sterilization.—The media used in determining the germ content of the samples of milk were sterilized in test tubes in the autoclave for fifteen minutes at 120° C. In order that all the test tubes might receive the same amount of heat, they were held during the process of sterilization in test-tube racks.

All the glassware and other laboratory apparatus withstanding dry heat were sterilized by subjecting them to 160° C. in a dry sterilizer for two hours or more.

The pails used for milking in Barn I were steamed for three minutes over a jet. In Barns II and III the pails were steamed in a sterilizer, which was a box constructed of galvanized iron. After such steaming, the pails were always examined for the presence of living bacteria which might have survived the steaming. This examination consisted of rinsing out each pail with 500 cc. of sterile water just previous to milking and then determining the number of bacteria in the rinse water.

The examination indicated that all the pails steamed in the sterilizer and 112 of the 130 pails steamed over the jet were free from bacteria. The remaining 18 pails steamed over the jet were not entirely sterile, but the number of bacteria found in them was extremely small and did not affect measurably the results of this study.

Taking of Samples.—All the samples were taken from the milk of the individual cows when the milker brought it in pails from the barn into the adjacent milk room. The milk was thus exposed to all the sources of contamination in the barn. After a thoro stirring with a sterile iron spoon fifteen inches long, the desired amount of milk was transferred by means of the spoon into a large test tube. The milk samples were immediately cooled to about 54° C., and were plated, as a rule, within one hour.

Dilutions and Plating.—Wide-mouthed, glass-stoppered bottles of 250-cc. capacity were used as dilution bottles. This type of bottle was used at the suggestion of Professor W. A. Stocking, Jr., of Cornell University, and was found to be an improvement on the ordinary dilution bottle with a cotton plug. The bottles were sterilized in the dry oven, and just before plating, the required amount of sterile water was introduced into each by means of a graduated pipette.

Two dilutions, 1 to 10 and 1 to 100, were made from each sample. For the first dilution 5 cc. of milk was added to 45 cc. of water, and for the second dilution, 1 cc. of milk was added to 99 cc. of water. Every bottle was then shaken violently, receiving 30 double shakes in such a manner that with each single stroke the bottle passed thru a distance of ten inches. From each dilution two plates were seeded, each one with 1 cc. of the bacterial suspension.

It is well known that in the quantitative bacteriological examination of milk by the plate method, plates seeded with the same milk will rarely develop the same number of colonies, even when the plating is done with care and accuracy. In order to ascertain the extent of variation due to the laboratory methods employed in this study, ten experiments were undertaken in each of which 100 plates were seeded with the same milk. The same dilution was used for all the plates in each experiment. The results from one of these experiments are shown in Table 1.

TABLE 1.—FREQUENCY DISTRIBUTION FOR NINETY-SIX PLATES[1] MADE FROM THE SAME BACTERIAL SUSPENSION

Class	Number of colonies per plate	Frequency distribution
1	110–120	111
2	121–130	卌 卌 1
3	131–140	卌 卌 卌 卌 卌 111
4	141–150	卌 卌 卌 卌 卌 卌 1111
5	151–160	卌 卌 1111
6	161–170	卌 1

[1] Four of the 100 plates were spoiled.

The mean number of colonies for all the plates in this experiment was 142, while the lowest count was 110 and the highest count was 170. In order to show the frequency distribution of the plates, they were divided into six classes, each of which had a class range of ten units. It will be seen from Table 1 that of the 96 plates counted, 62 fell into the third and fourth classes, having more than 130 and less than 151 colonies. With respect to variability, it is important to note that these individual counts showed very moderate variation. Indeed, no individual count deviated as much as 25 percent from the average. The other nine experiments on this subject showed approximately the same variation. According to the theory of statistics, the average of the counts for sets of four plates would tend to be about half as variable as the counts of the individual plates. Since, with but few exceptions, every determination in Tables 2 to 7 was an average of four plates it seems reasonable to conclude that the wide variations in the germ content of the samples shown in these tables were due primarily to variations in the number of bacteria actually present in the samples of milk and not to inaccuracies of the laboratory methods.

Medium.—The following medium was used thruout the entire study.

Agar shreds	15	grams
Liebig's meat extract	3	”
Witte's dry peptone	10	”
Lactose	10	”
Distilled water	1000	cc.

The reaction of the medium was adjusted to 1.0 percent normal acid to phenolphthalein.

Incubation and Counting.—All the plates were incubated for five days at 20° C., and for two days at 37° C. This length of time and the two temperatures of incubation were used in order to induce a larger number of the bacteria present in the milk to form visible colonies. According to Harding and Wilson,[1] the bacteria that form colonies at 37° C. but not at 20° C. may occasionally be present in the freshly drawn milk.

As stated above, two dilutions were made from each sample of milk and two plates were seeded from each dilution. All four plates from each sample were counted regardless of the number of bacteria on them, unless they showed some evidence of contamination. In Tables 2 to 7, therefore, the number of bacteria given for each sample of milk is an average based upon four plates.

RESULTS OF THE STUDY

As stated before, the samples were taken from the milk of individual cows. In Barn I, 511 samples were taken from 35 cows in 1914, and 349 samples from 37 cows in 1915. In Barn II, 360 samples were taken from 26 cows in 1914, and 207 samples from 21 cows in 1915. Of the 238 samples in Barn III, 161 were taken from 10 cows in 1914, and 77 from 9 cows in 1915. The data from the analyses of these samples are given in Tables 2 to 7.

---

[1] Harding, H. A., and Wilson, J. K. A Study of the Udder Flora of Cows. N. Y. (Geneva) Agr. Exp. Sta. Tech. Bul. 27. 1913.

TABLE 2.—GERM CONTENT OF THE INDIVIDUAL SAMPLES OF MILK: BARN I, 1914

Cow No.	26	35	55	63	73	74	110	111	112	130	134	135	150	152	154	155	156
Sample No.	Number of bacteria per cc. of milk																
1	305	5705	32250	3257	377	470	450	5485	6900	1672	252	270	575	375	192	420	612
2	250	565	3332	642	677	1170	1300	3512	3270	2760	710	135	592	897	425	655	770
3	337	112	218250	547	192	200	1290	10800	2522	927	167	197	907	572	842	1002	847
4	495	177	52287	1007	812	233	945	10500	1477	105	680	130	700	1587	900	255	505
5	1597	142	15925	1645	3627	487	497	3095	385	120	1890	170	235	156	1167	62	325
6	840	312	20237	110	1282	542	487	7287	1282	240	907	310	355	300	495	132	315
7	3800	197	10875	220	360	97	540	3122	1400	2255	210	365	322	365	1407	105	483
8	367	730	3850	192	445	272	266	6250	897	742	380	352	545	8060	760	406	477
9	745	557	13040	602	332	1183	335	6235	1815	477	1540	47	280	152	343	77	647
10	292	500	128095	447	300	2095	926	15812	1685	510	2770	205	890	90	2942	885	687
11	326	657	11077	302	1025	4850	245	4022	1247	77	3395	476	1457	450	4157	2560	1220
12	140	82	2960	790	387	1017	495	6467	672	110	2702	352	317	290	2285	2350	2117
13	2912	40	4400	263	1322	605	502	6200	765	107	615	1215	130	1042	840	107	1102
14	527	172	2255	72	2450	657	1032	11327	342	192	792	195	256	290	2557	140	1055
15	150	905	......	272	317	192	....	4380	5500	4000	457	....	50	....	352	40	281
16	....	....	......	142	....	....	....	4875	....	....	....	....	....	....	....	....	....
Average	872	723	25131	657	927	931	665	6835	2010	951	1164	325	506	1044	1307	613	763

TABLE 2.—*Concluded*

Cow No....	167	171	172	174	176	177	178	179	180	182	184	186	187	188	189	190	191	192
Sample No.	Number of bacteria per cc. of milk																	
1	985	412	1162	492	1685	1780	1215	135	28950	3425	6275	1502	327	58275	437	6225	1883	2130
2	1563	1480	5815	532	845	1020	487	1487	555	1475	5020	977	260	487	495	1115	1585	2182
3	1522	545	2600	265	553	887	1312	732	420	560	2987	1637	480	320	2502	910	3155	1410
4	1050	455	6355	70	1060	687	1332	1130	416	282	252	347	312	67	115	555	2622	1415
5	47	300	8505	170	720	890	650	2760	350	290	240	845	397	80	162	775	10135	587
6	282	272	7712	45	1162	1783	760	2177	235	330	233	820	663	130	60	705	320	627
7	77	670	2850	82	577	82	855	103	492	367	307	1363	1932	115	840	695	1412	506
8	67	840	2980	72	395	332	935	130	1225	975	1635	657	935	2847	190	1227	5937	1650
9	297	955	2060	155	805	260	567	263	2665	497	356	1327	377	82	92	337	657	737
10	225	490	937	17	332	700	1200	292	132	602	135	735	685	186	50	950	666	262
11	100	527	1370	200	1323	125	1087	1165	247	663	337	666	375	67	222	782	1295	242
12	180	607	3623	173	840	876	1032	436	350	536	250	740	772	126	100	647	442	592
13	66	395	4122	122	697	432	932	565	452	....	440	2400	432	....	112	710	455	265
14	100	315	4045	130	652	....	1100	355	482	....	222	800	247	....	252	927	427	253
15	45	765	....	225	755	....	412	....	972	....	2185	816	....	....	172	540	....	475
16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Average	444	602	3874	183	826	758	925	837	2529	833	1391	1042	585	5231	387	1140	2213	888

TABLE 3.—GERM CONTENT OF THE INDIVIDUAL SAMPLES OF MILK:
BARN I, 1915

Cow No.	26	55	73	74	110	112	130	134	135	150	152	155	156	167	171	172	174	176
Sample No.	Number of bacteria per cc. of milk																	
1	632	5750	2305	....	1272	1490	9212	1047	692	1962	14862	540	552	1342	1457	....	172	3972
2	350	51025	1007	165	2832	1862	4817	1530	775	1372	2493	307	720	6517	1120	6740	185	1982
3	587	11675	....	297	685	332	5245	737	1350	1430	33812	320	737	4502	1505	6665	2555	1555
4	3140	28725	....	400	590	3215	8340	737	936	542	897	372	1162	7162	4027	6390	355	2557
5	1567	23765	....	940	5290	3402	10980	445	750	852	4585	235	257	7107	930	11032	367	2757
6	657	55700	....	205	1207	4757	5487	397	662	652	2652	267	2065	5885	4430	2977	1140	4455
7	3617	24525	....	282	777	1440	10873	....	962	950	35675	525	1000	3653	1100	3327	2555	2570
8	735	22575	....	117	1460	1310	14070	285	760	622	2763	515	642	6502	2277	2097	180	6085
9	2050	5215	....	4660	1755	877	7465	1130	820	550	32855	432	1686	14312	4550	1937	120	1672
10	1455	39450	....	1807	930	3170	8012	1300	1002	1262	1092	575	802	3940	4192	2792	3545	1182
Average	1479	26840	1656	986	1679	2185	8250	845	870	1019	12168	408	962	6092	2558	4895	1117	2878

TABLE 3.—*Concluded*

Cow No.	177	179	180	181	187	188	189	190	191	192	193	194	195	196	198	199	200	202	203
Sample No.	Number of bacteria per cc. of milk																		
1	20350	112	480	....	1825	....	1087	4457	12737	685	1837	3400	1575	175	1045	3105	840	3600	630
2	2562	332	377	2517	897	150	1855	5530	2237	510	2582	1977	547	725	766	4555	1112	1750	1090
3	4710	332	700	2005	720	267	1087	6207	3607	555	2147	2072	6240	300	1250	5057	797	1665	1030
4	1230	1792	710	2342	802	352	1005	8302	6292	1205	2605	2147	360	403	952	5070	2115	3612	1300
5	5695	402	2012	550	1617	....	1475	....	4452	1095	3977	2090	5897	385	780	7240	4297	4632	1115
6	2182	1450	1100	6592	450	1422	1302	2207	2552	590	3055	8767	1615	586	840	3467	1052	5382	....
7	6383	605	447	3020	1815	732	1067	6830	3166	6097	3432	4007	1387	355	1280	2327	1680	1992	....
8	3130	1940	615	2242	732	2107	1775	5055	4635	2016	5577	1787	502	450	925	2590	830	932	....
9	2167	3100	275	1630	1167	465	2110	2892	2342	785	2907	1230	553	647	1372	1480	....	4385	....
10	1272	820	717	895	1165	250	1640	2615	3697	1225	1435	690	1312	517	917	5105	3097	6560	....
Average	4968	1088	743	2421	1119	718	1440	4899	4571	1476	2955	2816	1998	454	1012	3999	1757	3451	1033

TABLE 4.—GERM CONTENT OF THE INDIVIDUAL SAMPLES OF MILK: BARN II, 1914

Cow No..........	108	113	116	117	118	123	125	131	137	145	149	159	164
Sample No.	Number of bacteria per cc. of milk												
1	862	647	422	2397	1462	140	290	500	2587	1075	172	1562	762
2	582	100	90	700	402	75	127	232	1812	380	159	835	475
3	1470	185	125	1225	625	605	90	3230	2150	1222	142	....	985
4	1337	1307	50	1442	1677	157	232	855	1083	243	302	1030	1200
5	1837	707	815	4025	5462	365	1175	2220	1825	1720	610	2530	5075
6	1000	1221	668	793	12955	1078	3473	573	1400	1660	507	1845	514
7	737	232	95	156	96	23	108	1139	460	230	62	56	255
8	327	869	72	324	645	3	140	4001	482	312	273	107	128
9	42	400	107	70	90	157	189	1009	433	218	398	11	32
10	31	284	106	316	11	90	50	946	1264	52	151	239	83
11	450	665	160	1167	145	472	462	2970	1242	1860	715	567	1600
12	764	386	477	1787	722	572	1756	2767	1366	967	600	313	472
13	2247	1132	215	1285	270	930	640	1200	1662	317	920	960	1987
14	317	977	....	1560	280	192	1050	4075	1553	432	480	515	596
15	1550	425	....	1027	537	80	690	2062	1217	160	207	....	225
Average.....	**770**	**636**	**265**	**1217**	**2752**	**329**	**698**	**1878**	**1369**	**657**	**373**	**813**	**966**

TABLE 4.—*Concluded*

Cow No.	165	166	170	175	183	550	551	552	553	554	555	556	557
Sample No.	Number of bacteria per cc. of milk												
1	462	322	205	1362	906	342	2812	845	697	1050	1175	1745	510
2	45	112	....	3450	517	30	1417	120	1117	995	2692	437	820
3	387	240	27	2465	1950	575	2920	227	1977	797	5325	1730	480
4	130	75	47	....	270	602	815	352	587	837	970	667	....
5	1087	890	582	....	6612	4862	3250	532	757	1700	7505	2150	....
6	323	257	391	....	1459	1590	1782	1214	759	4633	380	4444	....
7	70	154	387	....	458	142	116	64	108	126	29	263	....
8	282	260	98	....	449	86	2000	70	445	257	115	92	....
9	....	116	51	....	225	1414	168	63	1073	107	98	100	....
10	355	53	67	....	487	98	44	357	1472	2689	368	95	....
11	350	167	255	....	1830	137	855	4025	745	1887	637	1090	....
12	647	685	352	....	562	200	1308	424	1067	1527	705	1630	....
13	326	182	457	....	3850	262	302	407	1317	4925	440	450	....
14	147	442	142	....	337	310	320	405	2012	905	385	1567	....
15	382	482	155	....	1287	383	722	447	1540	947	33000	300	....
Average	356	295	222	2425	1613	735	1258	635	1045	1292	3588	1117	603

TABLE 5.—GERM CONTENT OF THE INDIVIDUAL SAMPLES OF MILK:
BARN II, 1915

Cow No....	116	117	118	123	145	149	159	164	166	170
Sample No.	Number of bacteria per cc. of milk									
1	285	210	1452	3790	390	515	175	705	75	525
2	220	85	1047	145	605	1055	740	857	135	120
3	300	245	1290	275	110	460	150	45	455	335
4	517	180	462	547	3885	....	407	1530	182	307
5	256	...	2113	335	460	1100	166	765	30	115
6	372	267	1802	1665	655	1130	50	2267	60	636
7	256	85	4910	205	480	1010	250	670	77	1305
8	262	342	967	480	836	965	185	900	70	1992
9	142	205	3482	252	640	1185	397	652	175	467
10	475	85	135	317	805	692	592	1090	240	537
Average..	308	189	1766	801	886	901	311	948	149	633

TABLE 5.—*Concluded*

Cow No..........	183	501	550	551	552	556	558	559	560	561	562
Sample No.	Number of bacteria per cc. of milk										
1	735	150	3352	885	190	4020	260	1202	2133	90	165
2	4077	115	2350	300	80	1090	70	1372	25	215	595
3	585	280	1792	740	270	240	362	235	350	255	755
4	435	365	19032	570	242	477	272	255	14385	1587	1905
5	495	197	1347	210	...	2327	85	77	305	135	2107
6	677	195	1380	442	140	340	285	217	587	375	1880
7	1436	417	1845	176	140	690	247	50	20	75	1427
8	602	110	1122	82	382	1370	425	107	20	210	2042
9	745	170	1532	180	225	2980	422	1755	15	2280	1222
10	685	365	2242	380	245	215	235	285	50	265	1780
Average.....	1047	236	3599	396	212	1374	266	555	1789	548	1387

TABLE 6.—GERM CONTENT OF INDIVIDUAL SAMPLES OF MILK: BARN III, 1914

Cow No...	1003	1015	1018	1019	1025	1026	1031	1032	1033	1034
Sample No.	Number of bacteria per cc. of milk									
1	8775	8750	5547	4562	1987	11812	1815	9275	3792	307
2	7725	6705	8125	1925	5675	12325	2166	5625	2980	647
3	17750	8472	2350	2820	22146	19825	1483	6582	4955	1000
4	9875	1453	2120	865	1923	14175	1088	5260	2090	538
5	11650	3525	3675	563	970	16600	1110	3275	855	433
6	25312	3433	5735	7285	2130	13265	1932	6457	1757	652
7	15237	6110	10977	1092	3060	21075	5912	4733	5282	1072
8	8095	12108	3048	1223	2117	16875	2338	3788	3193	645
9	9725	4202	4977	1962	2045	14725	1510	1870	1825	857
10	10338	9380	2905	1620	3255	34525	2343	5673	2695	1198
11	29500	.....	4417	2287	3900	18400	2112	2285	4647	892
12	9700	.....	5210	3820	4860	14087	3215	6692	3915	5875
13	19150	.....	9792	2707	2555	63835	1620	1575	5367	20365
14	5825	.....	2215	5062	4498	9125	2340	4675	3895	3537
15	18950	.....	3505	3300	3552	26135	9690	1390	5925	2330
16	3425	.....	2177	3150	4452	7480	9725	5606	6480	3000
17	12013	.....	13735	2475	.....	10300	.....	3430	18520	1972
Average	13120	6414	5324	2748	4320	19092	3150	4603	4598	2667

TABLE 7.—GERM CONTENT OF INDIVIDUAL SAMPLES OF MILK: BARN III, 1915

Cow No..........	113	137	1015	1018	1019	1031	1032	1033	1034
Sample No.	Number of bacteria per cc. of milk								
1	20800	2347	7270	3197	3787	1252	4355	4515	342
2	13760	2277	4787	7117	1317	....	1745	4922	2787
3	2052	2767	.....	5025	7920	5687	6362	2957	2047
4	1315	2300	.....	9877	3967	8377	8690	3120	6467
5	1065	2230	17705	2890	1877	....	8970	8350	690
6	905	1175	6672	48600	6252	....	9472	4265	1230
7	2350	2257	.....	4235	2395	725	800	3807	2610
8	4885	1325	.....	4067	1752	....	2085	6392	1537
9	18602	887	9456	3777	2107	....	3292	5180	447
10	4185	3680	.....	4635	6225	....	....	....	1555
Average.....	6991	2124	9178	9342	3759	4010	5086	4834	1971

GERM CONTENT OF THE INDIVIDUAL SAMPLES OF MILK

Since the samples for this study were taken from the milk of the individual cows after it was brought in the pails from the barn into the milk room, the number of bacteria present in the milk was due to the collective influence of all the different sources of contamination at the barns. An examination of the foregoing tables shows that nearly every sample of milk had a different number of bacteria. Among the samples from Barn I, the lowest germ content was 17 and the highest was 218,250 bacteria per cubic centimeter of milk; in Barn II the lowest was 3 and the highest was 33,000; and in Barn III the lowest was 307 and the highest was 63,835. These are wide limits of variation in the germ content of milk produced under uniform barn conditions. However, the number of samples with high germ content was very small, especially in Barn II and Barn I; as a matter of fact, most of the samples of milk had an extremely low germ content. This is a conspicuous feature of the data, which is brought out more clearly by arranging the samples into the groups shown in Table 8.

TABLE 8.—GROUPING OF ALL MILK SAMPLES ACCORDING TO GERM CONTENT

	Below 1,000 per cc.	Between 1,000 and 5,000 per cc.	Between 5,000 and 10,000 per cc.	Between 10,000 and 50,000 per cc.	Over 50,000 per cc.
Barn I.......	472	297	56	29	6
Barn II......	405	153	4	5	0
Barn III.....	19	127	57	34	1
Total....	896	577	117	68	7

Of the 860 samples from Barn I, 472, or 54.9 percent, fall into the first group; 297, or 34.5 percent, fall into the second group; 56, or 6.5 percent, fall into the third group; 29, or 3.4 percent, fall into the fourth group; and 6, or 0.7 percent, fall into the fifth group. In Barn II, 405 samples, or 71.4 percent, fall into the first group; 153, or 27 percent, fall into the second group; 4, or 0.7 percent, into the third group; 5, or 0.9 percent, into the fourth group; and not a single sample is in the fifth group. In Barn III, 19 samples, or 8 percent, are in the first group; 127, or 53.3 percent,in the second group; 57, or 24 percent, in the third group; 34, or 14.2 percent, in the fourth group; and only one sample, or 0.5 percent, in the fifth group.

The influence of the barn conditions upon the germ content of milk from the individual cows is clearly seen in the above grouping of the samples. As judged by the general appearance of the barns and by the amount of labor devoted to the cleaning both of the barns and of the cows, Barn I was cleaner than Barn II, and Barn III was the dirtiest of the three barns. It is seen from the above data that the samples of milk from Barn III had, on the average, decidedly higher germ content that the samples from Barns I and II, but in view of the difference between the conditions in Barn III and the conditions in the other two barns it seems remarkable that so many samples from Barn III had such a low germ content and that the difference between the results from this barn and those from the other two barns was so small.

The comparison of the results from Barn I with those from Barn II, on the other hand, shows that there was a larger proportion of the samples from Barn II with a low germ content than from Barn I, in spite of the fact that the latter barn was cleaner. This and the fact that most of the samples from both barns had such low germ content clearly indicate that the barn conditions and operations in these two barns contributed but a small number of bacteria to the milk. Why there should have been a larger number of samples with high germ content from Barn I than from Barn II is not certain, but it will be noticed that most of the samples with high germ content in this barn came from certain few animals. The most conspicuous case was Cow 55. This animal persistently gave milk with high germ content and subsequent studies showed that her udder was the source of these larger numbers of bacteria in her milk.

AVERAGE GERM CONTENT OF THE MILK OF THE DIFFERENT ANIMALS

The average germ content of the milk of each animal was calculated from the data in Tables 2 to 7. It was obtained by adding the germ content of all the samples taken from the animal and then dividing the sum by the number of samples. The calculations were made for 1914 and 1915 separately. With but few exceptions, each average in 1914 represents fifteen to seventeen samples and in 1915 ten samples. In all, samples were taken from 89 different cows, 49 of which were milked during both years, so that 138 averages were obtained; these are shown in Table 9.

Of the 72 averages in Barn I, 30 were below 1,000 bacteria per cubic centimeter of milk, 35 were between 1,000 and 5,000, only 7 were over 5,000, and of these seven only 2 over 10,000. In Barn II, 30 of the 47 averages were below 1,000, and the highest average was only 3,599. In Barn III, all the averages were above 1,000 bacteria per cubic centimeter of milk, 11 were below 5,000, 6 were between 5,000 and 10,000, and 2 were over 10,000.

As in the germ content of the individual samples of milk, so also in the average germ content of the milk of the different animals, a considerable variation took place. For example, in Barn I Cow 174 had an average of only 183 bacteria per cubic centimeter, while Cow 55 had an average of 35,131. In Barn II, Cow 166 had an average of 149 bacteria, while Cow 550 averaged 3,599. In Barn III, Cows 1034 and 1026 averaged 1,971 and 19,093 bacteria, respectively. It is also of interest to note that the averages of the cows that were milked during both 1914 and 1915 were different for each year. In some cases the difference was very marked; for example, the average germ content of the milk from Cow 167 was 444 bacteria per cubic centimeter for 1914 and 6,092 for 1915, and the milk from Cow 152 averaged 1,044 and 12,168 bacteria, respectively, for the two years.

TABLE 9.—AVERAGE GERM CONTENT OF MILK OF INDIVIDUAL COWS FOR 1914 AND 1915 RESPECTIVELY

Barn I

Cow No.	Average germ content per cc.		Cow No.	Average germ content per cc.		Cow No.	Average germ content per cc.	
	1914	1915		1914	1915		1914	1915
26	872	1479	155	613	408	187	585	1110
35	723	.....	156	763	962	188	5231	718
55	35131	26840	167	444	6092	189	387	1440
63	657	.....	171	602	2558	190	1140	4899
73	927	1656	172	3874	4895	191	2213	4571
74	931	986	174	183	1117	192	888	1476
110	665	1679	176	826	2878	193	.....	2955
111	6835	.....	177	758	4968	194	.....	2816
112	2010	2185	178	925	.....	195	.....	1998
130	751	8250	179	837	1088	196	.....	454
134	1164	845	180	2529	743	198	.....	1012
135	325	870	181	.....	2421	199	.....	3999
150	506	1019	182	833	.....	200	.....	1757
152	1044	12168	184	1391	.....	202	.....	3451
154	1307	.....	186	1042	.....	203	.....	1033

Barn II

Cow No.	Average germ content per cc.		Cow No.	Average germ content per cc.		Cow No.	Average germ content per cc.	
	1914	1915		1914	1915		1914	1915
108	770	.....	159	373	311	553	1045	.....
113	636	.....	164	813	948	554	1292	.....
116	265	308	165	356	.....	555	3588	.....
117	1217	189	166	295	149	556	1117	1374
118	2752	1766	170	222	633	557	603	.....
123	329	801	175	2425	.....	558	.....	266
125	689	.....	183	1613	1047	559	.....	555
131	1878	.....	501	.....	236	560	.....	1789
137	1369	.....	550	735	3599	561	.....	548
145	657	886	551	1258	396	562	.....	1387
149	966	901	552	635	212	....	.....	.....

Barn III

Cow No.	Average germ content per cc.		Cow No.	Average germ content per cc.		Cow No.	Average germ content per cc.	
	1914	1915		1914	1915		1914	1915
113	.....	6991	1018	5324	9342	1031	3150	4010
137	.....	2124	1019	2748	3759	1032	4603	5086
1003	13120	.....	1025	4320	.....	1033	4598	4834
1015	6414	9178	1026	19092	.....	1034	2667	1971

AVERAGE GERM CONTENT OF ALL THE MILK AT DIFFERENT MILKINGS

In order to get the average germ content of all the milk produced at each milking, it was necessary to calculate it from the individual records, since all samples were taken from the milk of individual cows and not from mixed milk of all the cows. This average germ content was obtained, therefore, by dividing the total number of bacteria in all the milk produced at one milking by the total number of cubic centimeters of that milk. The results of that calculation are tabulated in Tables 10 to 15.

TABLE 10.—GERM CONTENT OF TOTAL DAILY MILK PRODUCTION: BARN I, 1914

Date	Total milk production in cc.	Total germ content of milk	Average germ content per cc. of milk	Number of cows milked
March 10	143 023	755 465 800	5 282	26
’’ 12	70 588	127 812 050	1 810	15
’’ 13	89 312	142 995 080	1 601	16
’’ 16	111 596	182 759 800	1 637	19
’’ 17	205 919	517 618 914	2 513	38
’’ 19	199 449	484 142 870	2 427	36
May 13	111 816	106 981 000	956	20
’’ 21	118 673	216 010 400	1 820	21
’’ 22	121 002	875 150 800	7 232	21
’’ 27	126 189	190 681 800	1 511	21
’’ 29	129 177	63 204 120	489	21
June 1	118 145	109 030 430	838	20
’’ 2	118 848	48 210 540	405	20
’’ 3	117 530	79 945 420	680	20
’’ 5	54 765	39 311 100	710	10
’’ 8	99 377	1 043 284 410	10 498	19
’’ 9	70 368	186 545 700	2 650	15
’’ 10	56 567	96 776 750	1 710	12
’’ 11	104 430	82 884 940	793	19
’’ 12	104 652	208 767 710	1 994	20
’’ 13	96 532	63 049 660	653	19
’’ 15	84 196	42 916 160	509	17
’’ 16, a. m.	71 335	75 607 499	1 059	15
’’ 16, p. m.	58 237	172 980 510	2 970	15
’’ 17, a. m.	65 533	40 232 670	613	14
’’ 17, p.m.	50 897	52 797 540	1 037	13
’’ 18, a. m.	68 874	69 369 560	1 007	13
’’ 18, p. m.	55 512	84 315 960	1 519	14
’’ 19, a. m.	61 973	52 388 390	845	14
’’ 19, p. m.	25 492	16 615 430	651	8

TABLE 11.—GERM CONTENT OF TOTAL DAILY MILK PRODUCTION: BARN I, 1915

Date	Total milk production in cc.	Total germ content of milk	Aver. germ content per cc. of milk	Number of cows milked
March 10	209 760	703 593 000	3 354	33
" 11	238 450	697 614 000	2 925	37
" 12	228 920	709 389 000	3 105	36
" 13	228 700	722 367 000	3 158	36
" 15	233 200	856 499 000	3 673	35
" 16	243 760	885 118 000	3 630	35
" 17	232 350	892 646 000	3 840	34
" 18	245 750	719 825 000	2 928	35
" 20	237 000	736 142 000	3 105	35

TABLE 12.—GERM CONTENT OF TOTAL DAILY MILK PRODUCTION: BARN II, 1914

Date	Total milk production in cc.	Total germ content of milk	Aver. germ content per cc. of milk	Number of cows milked
March 23	166 099	146 887 500	884	26
" 25	172 647	96 287 000	557	25
" 26	195 197	202 127 100	1 035	25
" 27	168 340	125 835 100	747	23
" 30	195 943	435 882 000	2 224	23
April 2	201 217	347 905 800	1 720	23
" 3	200 426	45 504 300	227	23
" 6	203 634	95 930 600	401	23
" 8	203 283	55 541 600	272	23
" 9	166 099	63 860 400	384	23
" 15	201 745	204 035 300	1 011	23
" 18	202 228	189 717 900	938	23
" 22	211 326	225 902 200	1 068	23
" 24	206 976	212 762 400	1 027	22
" 27	200 558	371 639 600	1 853	21

TABLE 13.—GERM CONTENT OF TOTAL DAILY MILK PRODUCTION: BARN II, 1915

Date	Total milk production in cc.	Total germ content of milk	Aver. germ content per cc. of milk	Number of cows milked
March 30	171 250	183 603 000	1 072	21
" 31	174 680	103 339 000	591	21
April 1	170 420	74 382 000	436	21
" 2	169 360	340 440 000	2 010	20
" 5	167 670	107 045 000	638	21
" 6	170 720	130 837 000	766	21
" 7	172 660	127 417 000	737	21
" 8	172 140	116 521 000	676	21
" 9	172 480	151 763 000	879	21
" 12	172 780	87 308 000	505	21

Table 14.—Germ Content of Total Daily Milk Production:
Barn III, 1914

Date	Total milk production in cc.	Total germ content of milk	Aver. germ content per cc. of milk	Number of cows milked
April 15	73 929	384 652 800	5 203	10
” 18	72 566	385 029 700	5 305	10
” 28	54 502	502 218 700	9 214	10
” 30	50 854	200 743 700	3 947	10
May 1	60 523	252 388 900	4 180	10
” 2	50 106	340 778 300	6 801	10
” 4	57 974	382 213 700	6 592	10
” 5	53 271	238 415 500	4 475	10
” 6 a. m	55 029	244 532 300	4 443	10
” 6 p. m	48 041	317 808 600	6 615	10
” 11	50 326	361 966 200	7 192	9
” 12 a. m	48 964	282 436 100	5 768	9
” 12 p. m	38 811	589 285 700	15 183	9
” 13	50 634	199 918 900	3 948	9
” 14	50 898	432 363 200	8 612	9
” 16	48 480	200 273 700	4 131	9
” 18	48 172	336 195 700	6 979	7

Table 15.—Germ Content of Total Daily Milk Production:
Barn III, 1915

Date	Total milk production in cc.	Total germ content of milk	Aver. germ content per cc. of milk	Number of cows milked
March 23	49 884	291 376 000	5 842	9
” 24	55 298	287 836 000	5 202	8
” 26	59 025	225 417 000	3 819	8
” 27	62 855	312 854 000	4 977	8
” 29	55 525	258 690 000	4 659	8
April 1	49 713	498 719 000	10 031	8
” 2	47 780	129 098 000	2 702	8
” 5	49 010	162 435 000	3 314	7
” 7	54 110	308 700 000	5 705	8
” 21	33 625	135 038 000	4 541	5

An examination of Tables 10 to 15 shows that the variation in the number of bacteria in the milk at the different milkings was surprisingly small in each barn.

This is particularly true of the results from Barn I for 1915 and from Barn II for 1914 and 1915. The lowest average daily count in Barn I during 1915 was 2,224 and the highest count was 3,840 bacteria per cubic centimeter. In Barn II for 1914 the lowest count was 227 and the highest count was 2,224, and for 1915 the lowest count was 436 and the highest count was 2,010 bacteria per cubic centimeter.

A somewhat more pronounced variation in the average daily germ content was obtained from Barn I for 1914. During that year, however, the samples at that barn were taken from only a part of the herd and, furthermore, not from the same cows at each milking, and it is probable that the greater variation was partly due to this procedure.

It is of interest to note that the few exceptionally high average daily counts, particularly the counts of May 22 and June 8, 1914, in Barn I, and those of May 12, 1914, and April 1, 1915, in Barn III, were due to exceptionally high counts in the milk of one or two cows. For example, in Barn I, on June 8, 1914, the total number of bacteria in the milk of the 19 cows from which the samples were taken was 1,043,284,410, of which number 958,814,000 were in the milk of Cow 55 and only 84,470,410 were in the milk of the remaining 18 cows. If this cow's milk had been excluded, the average germ content of the milk of the remaining 18 cows would have been about 1,000 bacteria per cubic centimeter; but with the milk of Cow 55 included, the germ content was 10,498 bacteria per cubic centimeter.

COMPARISON OF THE RESULTS FOR 1914 AND FOR 1915

As previously noted, in 1914 the udders of all the cows in the three barns were wiped with a damp cloth previous to each milking, but in 1915 this practice was discontinued. In all other respects, so far as possible, the same conditions and operations were maintained during both years. However, in a study of this nature certain factors which may affect the germ content of the milk are often beyond the control of the investigator. For example, in 1914 the study extended from March 10 to June 20, while in 1915 it was necessary to confine the study to March and April. According to Stocking, the different milkers may decidedly influence the germ content of the milk. In this study only two of the sixteen milkers employed in the three barns during the two years remained thruout the entire period of the experiment. Moreover, not all the cows milked in 1914 were milked in 1915. Some of those milked in 1914 were sold, and some new ones were added during the period between the experiments of 1914 and 1915. Thus 71 cows were milked in 1914 and 67 in 1915, and only 49 of these were milked during both years.

The difference between the data obtained in 1914 and in 1915 may be emphasized by a comparison based on the average counts of the different cows grouped as shown in Table 16.

It is seen from Table 16 that there was no appreciable difference in the grouping of the animals in Barn II and Barn III for the two respective years. On the other hand, in Barn I there were 22 cows in the first group and 10 in the second group in 1914 and only 8 cows in the first group and 25 cows in the second group in 1915. If the results are expressed in percentage, it will be found that in Barn I, 62.9 percent of the 35 cows milked in 1914 and only 21.6 percent of the 37 cows milked in 1915 were in the first group, while the second group contained only 28.6 percent of the cows in 1914 and 67.6 percent of the cows in 1915.

TABLE 16.—COMPARISON OF RESULTS IN 1914 AND 1915 BASED ON AVERAGE GERM CONTENT OF MILK OF THE INDIVIDUAL COWS

	Number of cows having average germ content of milk—		
	Below 1,000 per cc.	Between 1,000 and 5,000 per cc.	Over 5,000 per cc.
Barn I:			
1914	22	10	3
1915	8	25	4
Barn II:			
1914	15	11	0
1915	15	6	0
Barn III:			
1914	0	6	4
1915	0	5	4

When the data for each of the two years are compared on the basis of the average germ content, per cubic centimeter, of all the milk produced in each barn during the entire study, the relation shown in Table 17 is obtained.

TABLE 17.—COMPARISON OF RESULTS OF 1914 AND 1915 BASED ON THE AVERAGE GERM CONTENT OF MILK FOR THE THREE BARNS

	Average germ content per cc. of milk	
	1914	1915
Barn I	2 140	3 260
Barn II	973	830
Barn III	6 189	5 050
Average	2 188	2 552

Table 17 shows that the milk produced in Barn I had a germ content of 1,120 bacteria per cubic centimeter less in 1914 than in 1915, while the milk from Barn II had a germ content in 1914 of 143 bacteria more than in 1915, and the milk from Barn III had a germ content of 1,139 more in 1914 than in 1915.

The data for the two years may also be compared on the basis of the average germ content of all the milk produced in all three barns in 1914 and 1915, respectively. Such calculations show that the milk produced in 1914 during the course of the experiment had an average germ content of 2,188 bacteria per cubic centimeter and in 1915 an average germ content of 2,552 bacteria per cubic centimeter. In other words, every cubic centimeter of milk in 1914 contained 364 bacteria less than in 1915.

In all three barns the only operation that was intentionally altered during the two years was that of wiping the cow's udder with a damp cloth previous to each milking. The data for the two years show that in Barn I there was an appreciable increase and in Barn III an appreciable decrease in the germ content of the milk in 1915, and in Barn II the germ content of the milk was approximately the same for both years. It is evident that no conclusion can be drawn from the data concerning the relative importance of the practice of wiping the udders as compared with the other sources of contamination in these barns. The data, however, do point to the conclusion that the wiping of the udders under the conditions obtaining in these barns did not affect the germ content of the milk to any appreciable extent.

It is also to be noted that altho pronounced fluctuations in the numbers of bacteria do occur in the individual samples and in the averages of the different cows, the collective influence of all the sources of contamination on the germ content of the total daily milk production was remarkably uniform for both years in each of the three barns.

NUMBER OF BACTERIA ADDED TO THE MILK BY ALL THE BARN FACTORS IN EACH OF THE THREE BARNS

The results obtained from the 1,665 samples of milk from the three barns show pronounced variation. Accordingly, any attempt to estimate the combined influence of the various sources of contamination in any barn on the basis of a single set or a small number of sets of analyses gives no dependable results. On the other hand, the massing of the results from a large number of samples should give figures which are fairly representative. The data are therefore brought together in Table 18 so as to show the total milk production in each barn during the study, the total number of bacteria in the milk, and the average germ content per cubic centimeter of milk.

TABLE 18.—GERM CONTENT OF THE TOTAL MILK PRODUCTION FROM EACH BARN

	Total milk production in cc.	Total germ content of milk	Average germ content per cc. of milk
Barn I:			
1914	2 909 880	6 227 838 000	2 140
1915	2 343 540	7 640 708 000	3 260
Total	5 253 420	13 868 546 000	2 639
Barn II:			
1914	2 895 718	2 819 813 000	973
1915	1 714 160	1 422 655 000	830
Total	4 609 878	4 242 468 000	920
Barn III:			
1914	913 080	5 651 213 000	6 189
1915	516 825	2 610 163 000	5 050
Total	1 429 905	8 261 376 000	5 777

According to these calculations, all the sources of contamination in these barns contributed, as an average for the entire investigation, 2,639 bacteria per cubic centimeter to the milk from Barn I, 920 bacteria to the milk from Barn II, and 5,777 bacteria to the milk from Barn III.

The purpose of this investigation was, as stated before, to measure the collective influence of all the barn factors upon the germ content of the milk, and not to measure their influences separately. Nevertheless, the data obtained point to certain conclusions concerning the relative importance of some of the separate factors.

The influence of the udder of a given cow is confined to her own milk, and when her udder is a large factor, numerically, her milk will have a large germ content regardless of the degree of cleanliness of the barn and the cow. An examination of Table 9, page 42, brings out the fact that the number of bacteria added to the milk by the udder was small in the case of most of the animals. In Barns I and II, 61 cows were milked in 1914 and 58 cows in 1915. The average germ content of 60 of these 119 cows milked during the two years was less than 1,000 bacteria per cubic centimeter, and of 32 cows the average germ content was between 1,000 and 2,000 bacteria. It is evident, therefore, that since the small average counts of these 92 cows were due to all the barn factors, their udders could not have been numerically a large factor. Of the remaining 27 cows, 20 had average counts between 2,000 and 5,000; 4 averaged between 5,000 and 10,000; one averaged 12,168; and one had an average of 35,131 for 1914 and 26,840 for 1915. In the case of the last animal, Cow 55, additional study showed that, altho apparently healthy, she persistently gave milk with a high germ content, the source of which was her udder.

The average germ content of the milk from Barn I for the entire investigation was 2,639 bacteria per cubic centimeter. If Cow 55 were omitted from the calculations, the average would be reduced approximately 1,000 bacteria per cubic centimeter. In other words, the udder of Cow 55 alone contributed about two-fifths of all the bacteria that were found in all the milk produced in Barn I during the entire investigation. These results point to the conclusion that in the production of milk of low germ content, the udder of some cows may become the principal source of contamination.

This conclusion is supported by the studies of Hastings and Hoffman and of Harding and Wilson. Hastings and Hoffman[1] concluded that "there is no reason to believe that the average bacterial count of milk as it is drawn from the udders of healthy cows is over 1,000 bacteria per cubic centimeter." These authors, however, found that the milk from two cows in the herd studied averaged 30,700 and 38,800 bacteria per cubic centimeter, respectively. In a more extensive study, Harding and Wilson[1] examined 1,230 samples of milk taken directly from the udders of 78 cows. This examination showed that, on the average, only 428 bacteria per cubic centimeter were added to the milk by the udders of these cows, but that 8 percent of the samples contained more than 1,000 bacteria per cubic centimeter, and the highest count was 16,610.

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[1] Hastings, E. G., and Hoffman, C. Bacterial Content of the Milk of Individual Animals. Wis. Agr. Exp. Sta. Res. Bul. 6, pp. 189-196. 1907.

The 2,639 bacteria per cubic centimeter in the milk from Barn I may be considered to have been derived from three separate sources; namely, the udder of Cow 55, the udders of the remaining cows, and the barn factors. Since none of the cows in Barn II gave uniformly high counts, the 920 bacteria per cubic centimeter of the milk from this barn may be considered as having been derived from two sources—the udders of the cows and the barn factors. If it is assumed that approximately 500 bacteria per cubic centimeter were added by the cow's udders, it will be seen that the conditions and operations at Barn I, omitting Cow 55 from consideration, contributed approximately 1,100 bacteria per cubic centimeter of milk, and at Barn II about 400.

The general appearances of Barns I and II would seem to indicate that Barn I was the cleaner; and yet from the above deductions it is seen that more bacteria were added to the milk at Barn I than at Barn II. It might be argued from the results obtained at these two barns that a dirty barn does not contribute more bacteria to the milk than a clean barn. Such conclusion, however, would be against a well established fact. This apparent discrepancy is only a side issue to the general problem, and it would be a mere conjecture to attempt to explain it. The real significance of the results from these two barns lies in the fact that the number of bacteria in the milk from both barns was remarkably small, and that the difference in the conditions and the operations in the two barns exerted practically negligible influence upon the germ content of the milk.

Even more significant are the results from Barn III. The average contamination here was 5,777 bacteria per cubic centimeter. This milk, so far as the germ content was concerned, would meet the requirements for certified milk, and yet the conditions of the barn as to cleanliness were such that it is doubtful whether the milk produced here would have been admitted to the milk supply of some cities.

These results must not be construed as a defense of dirty barns. They simply point to the fact that the large numbers of bacteria commonly found in milk do not have their origin in the barn.

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[1] Harding, H. A., and Wilson, J. K. A Study of the Udder Flora of Cows. N. Y. (Geneva) Agr. Exp. Sta. Tech. Bul. 27. 1913.

SUMMARY

This study was conducted in three dairy barns, differing widely in the degree of cleanliness. Samples were taken from the milk of individual cows when the milk was brought from the barn to the milk room and the germ content of each sample was then determined.

A total of 1,665 samples were taken from 138 cows. The samples were collected during March, April, May, and June in 1914 and again during March and April in 1915.

While the germ content of the individual samples varied from 3 to 218,250 bacteria per cubic centimeter, the large majority of the samples in all three barns had a low germ content. The average germ content of the milk of individual cows was low in most cases. Cow 55 had the highest average of 35,131 bacteria per cubic centimeter of milk, but the udder of this animal was the source of this high average. The average germ content of all the milk produced at each milking was over 10,000 only once in Barn I and only twice in Barn III, and in Barn II the highest average was only 2,224.

The milk produced in 1914 and in 1915 had approximately the same germ content. The average germ content of all the milk produced during the entire study was 2,639 bacteria per cubic centimeter in Barn I, 920 in Barn II, and 5,777 in Barn III.

CONCLUSIONS

The study of these three barns shows that even under wide extremes in barn conditions it is possible to produce milk with a germ content of less than 10,000 bacteria per cubic centimeter when the utensils are properly prepared.

These intensive studies made at the Illinois and at the New York Agricultural Experiment Stations, together with accordant observations upon about twenty-five ordinary dairy barns by the former institution[1] and upon thirty-four dairy barns by the latter institution,[2] make it plain that when the influence of utensils is excluded, the dairy barns exert little measurable influence upon the germ content of the milk.

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[1] In connection with other studies not included in this bulletin, samples of milk from about one hundred different barns have been recently examined for germ content, and in no case did the varied conditions in the barn have any marked effect upon the germ content of the milk.

[2] Brew, James D. Milk Quality as Determined by Present Dairy Score Card. N. Y. (Geneva) Agr. Exp. Sta. Bul. 398. 1915.

ACKNOWLEDGMENT

Whenever attempts are made to measure barn activities, the attitude of the workmen becomes an important element in the success of the study. Because such measurements add something to their labor, the men may become antagonistic; or because such measurements may be taken as an index of the care with which they do their work, they may modify their actions during such tests so as to lead to abnormal results. Either of these attitudes may modify the results and endanger the conclusions. Accordingly, the colleague who has immediate charge of the barn workmen becomes a vital part of the investigation and his influence in keeping barn conditions normal during the progress of the study is a large factor in the success of the work.

Both because of the harmonious relations which have existed and on account of numerous check experiments, we believe that the results here given are representative of the conditions regularly obtaining in the three barns in which this investigation was made. These barns were under the supervision of Professor W. J. Fraser, and Messrs. R. S. Hulce and W. T. Crandall. The authors are greatly indebted to these colleagues for their hearty cooperation, without which the investigation could not have been performed successfully.

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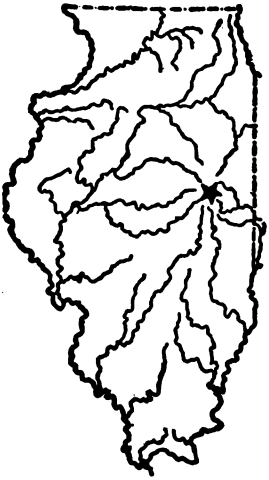
Agricultural Experiment Station

BULLETIN No. 200

DIGESTION EXPERIMENTS WITH PIGS
WITH SPECIAL REFERENCE TO THE INFLUENCE OF ONE FEED UPON ANOTHER, AND TO THE INDIVIDUALITY OF PIGS

BY H. S. GRINDLEY, W. J. CARMICHAEL, AND C. I. NEWLIN



URBANA, ILLINOIS, MAY, 1917

The Station

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DIGESTION EXPERIMENTS WITH PIGS

WITH SPECIAL REFERENCE

TO THE INFLUENCE OF ONE FEED UPON ANOTHER, AND TO THE INDIVIDUALITY OF PIGS

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OBJECTS OF THE EXPERIMENTS

The objects of the experiments reported in this bulletin were as follows: (a) to determine the influence of one feed upon the digestibility of the nutrients of another feed; (b) to study the individuality of pigs as to the thoroness with which they digest their feed; and (c) to determine the coefficients of apparent digestibility[1] of the nutrients of the following rations: (1) wheat flour middlings, (2) ground corn, (3) ground barley, (4) wheat flour middlings and ground corn in the ratio of 1 to 1, (5) ground barley and ground corn in the ratio of 1 to 1, and (6) tankage and ground corn in the ratio of 1 to 7.5. In order to secure experimental data that would answer the questions suggested by the above objects, ground corn, wheat flour middlings, and tankage were the feeds used in the first series of experiments; and ground corn, ground barley, and tankage were used in the second series of experiments.

FIRST SERIES OF EXPERIMENTS, 1913-1914

Plan

Four cross-bred Berkshire-Chester White barrows a little over seven months old, and all from the same litter, were selected for this work and put into specially constructed pens. These pens (Fig. 1) were large enough to allow the pigs to turn around conveniently, and were raised some three feet from the floor to enable an easy collection of the urine. They were provided with removable galvanized-iron feed troughs (Fig. 2) and with hinged doors, thru which the animals were driven to the weighing crate. The floor, consisting of a strong wire screen, fitted tightly over a galvanized-iron hopper leading to the urine pail (Fig. 3). No chemical analyses of the urines were made. The feces, collected in rubber-lined canvas bags held in place by means of a specially constructed harness (Fig. 4), were removed each day and placed in friction-top cans.

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[1] Strictly speaking, the coefficients of the *real* digestibility of the nutrients of feeds cannot as yet be determined, for it is impossible to estimate accurately in the feces, either the metabolic products of intestinal action or the products resulting from tissue metabolism that are excreted thru the intestinal walls into the alimentary canal. Therefore, thruout this bulletin the coefficients of digestibility represent the coefficients of *apparent* digestibility; that is, merely the differences between the weights of the nutrients in the feeds and in the feces expressed in percent of the former.

Corn and wheat flour middlings were chosen because they are two of the most common and practical feeds used for swine in the corn belt. No. 2 yellow corn was used. Digester tankage (meat meal) containing over 60 percent of protein was fed in two periods of the experiment. The barrows were fed twice daily, at 7 a. m. and 5 p. m. The different rations were given in amounts that the pigs would clean up readily, this quantity being determined during a period of several days' duration immediately preceding the experiments proper. Each of the rations was mixed with a definite amount of water (as much as the pigs would take) and fed as a moderately thin slop.

The first ration for which the coefficients of digestibility were determined consisted approximately of 2.17 pounds of middlings per 100 pounds live weight; the second, of 1.04 pounds of middlings and 1.04 pounds of ground corn per 100 pounds live weight; the third, of 2.06 pounds of ground corn per 100 pounds live weight; the fourth of 1.84 pounds of middlings per 100 pounds live weight; and the fifth, of 1.74 pounds of ground corn and 0.23 pounds of tankage per 100 pounds live weight. Each of these rations was fed for two ten-day test periods, during which time composite samples of the feeds and feces were taken for chemical analysis.

Each group of the two ten-day test periods was preceded by a preliminary period of twenty-five to thirty-two days' duration. During the first seven to ten days of each preliminary period, the change in the kinds of feed was made; during the remainder of the preliminary period, the pigs were fed the same ration in the same amounts per hundred pounds of live weight that they were to be fed during the two test periods immediately following. During the last ten days of each preliminary period, the pigs were in their pens, fully harnessed, in order that they might have sufficient time to become accustomed to the experimental conditions before any data were recorded.

CHEMICAL COMPOSITION OF FEEDS AND FECES; AND WEIGHTS OF PIGS, FEEDS, WATER, FECES, AND URINE

The chemical composition of the feeds and fresh feces are given in Tables 1 and 3, respectively. The weights of the pigs, the feeds, the water, the feces, and the urine for each experimental period are given in Table 2.

From the data given in Table 2, it will be noted that the weights of the feces per pound of feed varied markedly depending upon the character of the ration. The average weights of the fresh feces per pound of feed were as follows: In Periods 1 and 2, and 7 and 8, in which middlings alone were fed, 1.13 and 0.99 pounds, respectively; in Periods 3 and 4, in which middlings and ground corn in the ratio of 1 to 1 were fed, 0.74 pounds; in Periods 9 and 10, in which tankage and ground corn in the ratio of 1 to 7.5 were fed, 0.39 pounds; and in Periods 5 and 6, in which ground corn alone was fed, 0.355 pounds.

Examination of Table 3, giving the composition of the fresh feces, and of Table 4, showing the coefficients of digestibility of the nutrients of the rations, shows that the above differences in weights of the feces per pound of feed due to the character of the ration consumed, can be traced, in large part at least, to the variations in the water content of the feces and to the variations in the coefficients of digestibility of the dry substance of the rations. Thus, the average water content of the feces for the several periods was as follows: Periods 1 and 2, and 7 and 8, in which middlings alone were fed, 79.83 and 76.51 percent, respectively; Periods 3 and 4, in which middlings and ground corn in the ratio of 1 to 1 were fed, 75.15 percent; Periods 9 and 10, in which tankage and ground corn in the ratio of 1 to 7.5 were fed, 69.83; and Periods 5 and 6, in which ground corn alone was fed, 70.28 percent.

The average coefficients of digestibility of the dry substance of the rations for the several periods were as follows: Periods 1 and 2, and 7 and 8, in which middlings alone were fed, 74.7 and 74.2, respectively; Periods 3 and 4, in which middlings and ground corn in the ratio of 1 to 1 were fed, 79.1; Periods 9 and 10, in which tankage and ground corn in the ratio of 1 to 7.5 were fed, 86.8; and Periods 5 and 6, in which ground corn alone was fed, 87.9.

TABLE 1.—CHEMICAL COMPOSITION OF THE FEEDS
(Results expressed in percent of the fresh substance)

Kind of feed	Used in periods	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract	Crude ash	Non-protein nitrogen	Total nitrogen
Ground corn....	3, 4, 5, 6	86.38	71.74	1.95	8.45	2.95	1.29	0.177	1.352
Ground corn....	9, 10	88.47	71.63	2.31	9.30	3.95	1.28	0.156	1.489
Average.....	....	87.42	71.68	2.13	8.87	3.45	1.28	0.166	1.420
Wheat flour middlings....	1, 2	89.64	54.98	5.92	18.33	5.85	4.58	0.615	2.932
Wheat flour middlings....	3, 4, 7, 8	89.95	54.98	6.01	18.06	6.05	4.75	0.631	2.890
Average.....	....	89.79	54.98	5.97	18.19	5.95	4.66	0.623	2.911
Tankage.......	9, 10	92.06	3.96	3.10	62.58	7.56	14.84	3.382	10.013

TABLE 2.—WEIGHTS OF PIGS, FEEDS, WATER, FECES, AND URINE
(Results expressed in pounds)

Pig	Live weight	Feeds consumed				Water	Total feces	Feces per lb. of feed	Total urine[1]
		Mid-dlings	Ground corn	Total	Per day per 100 lbs. live weight				
First Test Period. December 18 to 27, 1913. Ten days. Middlings									
113	181.8	39.60	.....	39.60	2.18	158.40	44.67	1.13	......
213	181.5	39.60	.....	39.60	2.18	158.40	48.31	1.22	......
313	149.4	33.00	.....	33.00	2.21	132.00	37.50	1.14	......
413	149.3	33.00	.....	33.00	2.21	132.00	35.23	1.07	......
Average	165.5	36.30	.....	36.30	2.20	145.20	41.43	1.14	......
Second Test Period. December 28, 1913 to January 6, 1914. Ten days. Middlings									
113	186.5	39.60	.....	39.60	2.12	158.40	45.37	1.15	......
213	186.7	39.60	.....	39.60	2.12	158.40	46.39	1.17	......
313	153.1	33.00	.....	33.00	2.16	132.00	35.95	1.09	......
413	154.5	33.00	.....	33.00	2.14	132.00	35.36	1.07	......
Average	170.2	36.30	.....	36.30	2.14	145.20	40.77	1.12	......
Third Test Period. January 24 to February 2, 1914. Ten days. Middlings and ground corn (1 to 1)									
113	207.0	22.00	22.00	44.00	2.13	176.00	31.99	0.73	120.04[2]
213	207.6	22.00	22.00	44.00	2.12	176.00	32.33	0.73	136.38
313	174.3	18.00	18.00	36.00	2.07	144.00	25.72	0.71	113.05
413	172.4	18.00	18.00	36.00	2.09	144.00	26.18	0.73	114.32
Average	190.3	20.00	20.00	40.00	2.10	160.00	29.05	0.72	120.95
Fourth Test Period. February 3 to 12, 1914. Ten days. Middlings and ground corn (1 to 1)									
113	213.2	22.00	22.00	44.00	2.06	176.00	33.84	0.77	134.42
213	212.0	22.00	22.00	44.00	2.08	176.00	33.63	0.76	136.80
313	177.0	18.00	18.00	36.00	2.03	144.00	26.51	0.74	104.86[2]
413	175.7	18.00	18.00	36.00	2.05	144.00	27.54	0.76	90.84[3]
Average	194.5	20.00	20.00	40.00	2.06	160.00	30.38	0.76	116.73
Fifth Test Period. March 7 to 17, 1914. Ten days. Ground corn									
113	228.0	.....	48.00	48.00	2.11	180.90	17.12	0.36	153.95
213	231.4	.....	48.00	48.00	2.07	164.70	18.85	0.39	143.64
313	193.3	.....	40.00	40.00	2.07	157.10	13.62	0.34	136.69
413	192.5	.....	40.00	40.00	2.08	120.00	13.58	0.34	103.71
Average	211.3	.....	44.00	44.00	2.08	155.67	15.79	0.36	134.50

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[1] Weight of urine for first and second periods not recorded.
[2] Weight for 9 days only.
[3] Weight for 8 days only.

TABLE 2.—*Concluded*

Pig	Live weight	Feeds consumed				Water	Total feces	Feces per lb. of feed	Total urine
		Middlings	Ground corn	Total	Per day per 100 lbs. live weight				
Sixth Test Period. March 18 to 27, 1914. Ten days. Ground corn									
113	234.2	.....	48.00	48.00	2.05	160.40	16.80	0.35	137.19
213	236.0	.....	48.00	48.00	2.03	181.80	17.97	0.37	155.07
313	197.3	.....	40.00	40.00	2.03	160.00	13.07	0.33	140.35
413	196.8	.....	40.00	40.00	2.03	125.50	14.00	0.35	111.10
Average	216.1	.....	44.00	44.00	2.04	156.92	15.46	0.35	135.93
Seventh Test Period. April 26 to May 5, 1914. Ten days. Middlings									
113	283.0	52.00	.....	52.00	1.84	208.00	57.00	1.10	150.94
213	283.2	52.00	.....	52.00	1.84	208.00	52.66	1.01	155.93
313	248.3	46.00	.....	46.00	1.85	184.00	45.57	0.99	140.66
413	240.8	46.00	.....	46.00	1.91	184.00	46.89	1.02	142.76
Average	263.8	49.00	.....	49.00	1.86	196.00	50.53	1.03	147.57
Eighth Test Period. May 6 to 15, 1914. Ten days. Middlings									
113	292.3	52.00	.....	52.00	1.78	208.0	51.64	0.99	155.32
213	290.7	52.00	.....	52.00	1.79	208.0	50.14	0.96	155.81
313	255.3	46.00	.....	46.00	1.80	184.0	44.67	0.97	142.21
413	247.7	46.00	.....	46.00	1.86	184.0	40.94	0.89	143.65
Average	271.5	49.00	.....	49.00	1.81	196.0	46.85	0.95	149.25
Ninth Test Period. June 5 to 14, 1914. Ten days. Tankage and ground corn (1 to 7.5)									
113	332.0	8.00	60.00	68.00	2.05	210.50	24.57	0.36	100.62
213	332.7	8.00	60.00	68.00	2.04	201.00	29.72	0.44	102.91
313	292.4	6.60	50.00	56.60	1.94	191.20	21.10	0.37	110.28
413	283.4	6.60	50.00	56.60	2.00	176.60	23.59	0.42	113.20
Average	310.1	7.30	55.00	62.30	2.01	194.82	24.74	0.40	106.75
Tenth Test Period. June 15 to 24, 1914. Ten days. Tankage and ground corn (1 to 7.5)									
113	347.4	8.00	60.00	68.00	1.96	205.10	26.04	0.38	126.70
213	346.4	8.00	60.00	68.00	1.96	193.50	29.40	0.43	119.02
313	302.6	6.60	50.00	56.60	1.87	191.80	19.59	0.35	127.79
413	297.1	6.60	50.00	56.60	1.91	157.70	21.43	0.38	98.03
Average	323.4	7.30	55.00	62.30	1.93	187.02	24.11	0.38	117.88

TABLE 3.—CHEMICAL COMPOSITION OF THE FECES
(Results expressed in percent of fresh substance)

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract	Crude ash	Non-protein nitrogen	Total nitrogen	Nitrogen insoluble in acid pepsin
First Test Period. December 18 to 27, 1913. Ten days. Middlings									
113	19.64	8.05	4.12	3.47	0.93	3.02	0.161	0.555	0.205
213	19.34	7.99	3.87	3.39	1.07	3.03	0.157	0.542	0.213
313	18.88	7.84	3.97	3.14	0.88	3.06	0.158	0.502	0.210
413	21.08	8.89	4.14	3.79	1.06	3.20	0.163	0.607	0.198
Average	19.74	8.19	4.02	3.45	0.98	3.08	0.160	0.551	0.206
Second Test Period. December 28, 1913 to January 6, 1914. Ten days. Middlings									
113	19.34	8.35	4.02	3.19	0.66	3.13	0.189	0.510	0.205
213	19.78	8.61	4.07	3.20	0.88	3.03	0.172	0.511	0.194
313	21.07	9.46	4.63	2.94	0.76	3.27	0.140	0.471	0.208
413	22.23	10.39	3.64	3.83	1.11	3.26	0.140	0.590	0.187
Average	20.60	9.20	4.09	3.29	0.85	3.17	0.160	0.520	0.198
Third Test Period. January 24 to February 2, 1914. Ten days. Middlings and ground corn (1 to 1)									
113	25.38	12.62	4.48	3.97	1.34	2.97	0.129	0.635	0.228
213	25.39	12.62	4.27	4.24	1.31	2.95	0.129	0.678	0.201
313	24.28	11.77	4.96	3.42	0.80	3.34	0.098	0.546	0.293
413	24.71	11.62	4.82	4.55	0.73	3.01	0.130	0.727	0.260
Average	24.94	12.16	4.63	4.04	1.04	3.07	0.121	0.646	0.245
Fourth Test Period. February 3 to 12, 1914. Ten days. Middlings and ground corn (1 to 1)									
113	24.61	11.25	5.23	3.78	1.29	3.06	0.129	0.605	0.224
213	24.28	12.05	4.35	4.10	0.93	2.85	0.152	0.655	0.181
313	25.18	12.00	5.31	3.93	0.79	3.14	0.207	0.628	0.183
413	25.01	12.08	4.76	4.51	0.87	2.85	0.177	0.721	0.257
Average	24.77	11.85	4.91	4.08	0.97	2.97	0.166	0.652	0.211
Fifth Test Period. March 7 to 17, 1914. Ten days. Ground corn									
113	27.41	13.90	3.98	5.49	1.39	2.66	0.180	0.878	0.206
213	29.43	13.77	3.91	6.08	3.21	2.46	0.172	0.973	0.183
313	29.83	15.92	3.43	5.90	1.80	2.76	0.177	0.944	0.219
413	29.25	13.65	4.03	5.84	3.18	2.56	0.170	0.935	0.210
Average	28.98	14.31	3.84	5.83	2.39	2.61	0.175	0.932	0.204

TABLE 3.—*Concluded*

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract	Crude ash	Non-protein nitrogen	Total nitrogen	Nitrogen insoluble in acid pepsin
Sixth Test Period. March 18 to 27, 1914. Ten Days. Ground corn									
113	29.71	16.08	3.67	5.53	1.49	2.94	0.257	0.884	0.216
213	31.52	15.33	4.15	6.58	2.78	2.67	0.223	1.053	0.188
313	29.41	14.49	3.41	6.12	2.51	2.87	0.238	0.979	0.234
413	31.21	16.03	3.88	6.06	2.46	2.79	0.239	0.969	0.290
Average	30.46	15.48	3.78	6.07	2.31	2.82	0.239	0.971	0.232
Seventh Test Period. April 26 to May 5, 1914. Ten days. Middlings									
113	21.90	10.13	4.63	3.41	0.60	3.14	0.204	0.545	0.158
213	23.79	11.66	4.40	3.76	0.68	3.29	0.241	0.602	0.174
313	22.73	11.03	4.60	3.08	0.73	3.30	0.166	0.492	0.194
413	24.58	11.63	5.00	3.85	0.83	3.27	0.199	0.617	0.209
Average	23.25	11.11	4.66	3.52	0.71	3.25	0.202	0.564	0.184
Eighth Test Period. May 6 to 15, 1914. Ten days. Middlings									
113	22.29	9.96	4.96	3.52	0.43	3.41	0.201	0.563	0.206
213	23.61	10.91	5.02	3.65	0.63	3.40	0.198	0.583	0.207
313	23.68	10.73	4.97	3.27	0.73	3.58	0.146	0.523	0.196
413	25.34	11.59	5.34	4.04	0.89	3.49	0.207	0.647	0.217
Average	23.73	10.80	5.07	3.62	0.67	3.47	0.188	0.579	0.206
Ninth Test Period. June 5 to 14, 1914. Ten days. Tankage and ground corn (1 to 7.5)									
113	31.33	13.12	3.34	9.46	1.61	3.80	0.340	1.514	0.408
213	28.51	11.51	3.25	9.59	1.23	2.93	0.388	1.535	0.484
313	29.78	11.52	2.98	10.40	0.90	3.99	0.351	1.664	0.771
413	30.92	13.08	3.19	9.73	2.09	2.82	0.303	1.557	0.493
Average	30.14	12.31	3.19	9.80	1.46	3.38	0.346	1.568	0.539
Tenth Test Period. June 15 to 24, 1914. Ten days. Tankage and ground corn (1 to 7.5)									
113	30.85	12.92	2.97	9.38	1.53	4.05	0.386	1.501	0.557
213	30.13	12.53	2.83	9.68	1.76	3.33	0.403	1.548	0.608
313	29.59	11.13	2.75	10.32	1.57	3.83	0.371	1.652	0.725
413	30.22	12.05	2.89	10.17	1.96	3.14	0.369	1.628	0.579
Average	30.20	12.16	2.86	9.89	1.70	3.59	0.382	1.582	0.617

COEFFICIENTS OF DIGESTIBILITY OF THE NUTRIENTS OF THE RATIONS

The coefficients of the digestibility of the nutrients of the rations for the four pigs, as determined directly, for the ten periods of this series of experiments are given in Tables 4 and 5.

Wheat Flour Middlings.—It is evident from Table 4 that the coefficients of the digestibility of the nutrients of wheat flour middlings, when fed alone in Periods 1, 2, 7, and 8, varied somewhat for the different animals during the same experimental period. It is also apparent that the coefficients varied considerably for the same animal in the different periods. This is especially true of the ether extract and the crude fiber. It is possible that the differences in the coefficients for Periods 1 and 2, on the one hand, and Periods 7 and 8, on the other hand, are due to the differences in the age and the weight of the animals. The pigs were about four and one-half months older, and weighed about 100 pounds more, during Periods 7 and 8 than during Periods 1 and 2.

The average coefficients of digestibility of the nutrients of wheat flour middlings when fed alone to each of the four pigs for the four ten-day periods (sixteen digestion trials) were as follows: dry substance, 74.4; nitrogen-free extract, 81.2; crude fiber, 21.0; crude protein, 80.0; and ether extract, 85.5.

Ground Corn.—The coefficients of digestibility of the nutrients of ground corn fed alone, in Periods 5 and 6, varied somewhat for the different pigs during the same period. The average coefficients of the dry substance, the nitrogen-free extract, and the crude protein of the ground corn agreed very closely for the two periods; the average values for the crude fiber and the ether extract did not vary much.

The average coefficients of digestibility of the nutrients of the ground corn when fed alone to each of the four pigs for the two ten-day periods (eight digestion trials) were as follows: dry substance, 87.9; nitrogen-free extract, 92.7; crude fiber, 30.8; crude protein, 75.0; and ether extract, 71.6. The average coefficients of the nutrients of ground corn when fed alone in four digestion trials previously reported from this station[1] were as follows: dry substance, 87.7; nitrogen-free extract, 93.6; crude fiber, 31.8; crude protein, 79.3; and ether extract, 71.3.

On comparing the average coefficients of the nutrients of the ration of ground corn fed alone with the corresponding averages for the ration of wheat flour middlings fed alone, it will be noted that the dry substance, the nitrogen-free extract, and the crude fiber of the ground corn were digested much more thoroly than the corresponding nutrients of the wheat flour middlings alone, while the crude protein and the ether extract of the ground corn were digested much less thoroly than those of the wheat flour middlings.

Wheat Flour Middlings and Ground Corn (1 to 1).—The coefficients of digestibility of the nutrients of the ration of wheat flour middlings and ground corn fed together in the ratio of 1 to 1, in Periods 3 and 4, varied somewhat for the different animals during the same period. The average coefficients of digestibility of all the nutrients of this ration, except the crude fiber, agreed very closely for the two periods.

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[1] Dietrich and Grindley: Ill. Agr. Exp. Sta. Bul. 170.

The average coefficients of digestibility of the nutrients of the ration of wheat flour middlings and ground corn fed together in the ratio of 1 to 1 to each of the four pigs for the two ten-day periods (eight digestion trials) were as follows: dry substance, 79.1; nitrogen-free extract, 85.9; crude fiber, 12.1; crude protein, 77.3; and ether extract, 83.4.

On comparing the average coefficients of the nutrients of the ration of wheat flour middlings and ground corn fed together in the ratio of 1 to 1 with those of each of the rations of wheat flour middlings and of ground corn when fed alone, it will be noted that the coefficients of the nutrients for the ration of middlings and corn were in all cases, excepting that of the crude fiber, intermediate between those of the middlings fed alone and those of the corn fed alone.

Tankage and Ground Corn (1 to 7.5).—The coefficients of digestibility of the nutrients of the ration of tankage and ground corn fed together in the ratio of 1 to 7.5, in Periods 9 and 10, varied significantly for the different pigs during the same period. The average coefficients of all the nutrients of this ration, except the crude fiber, agreed closely for the two experimental periods.

The average coefficients of digestibility of the nutrients of the ration of tankage and ground corn fed together in the ratio of 1 to 7.5 to each of the four pigs for the two ten-day periods (eight digestion trials) were as follows: dry substance, 86.7; nitrogen-free extract, 92.5; crude fiber, 50.8; crude protein, 75.3; and ether extract, 85.8. The average coefficients of the nutrients of tankage and ground corn when fed together in ratios varying from 1:4 to 1:6 in six digestion trials previously reported from this station[1] were as follows: dry substance, 83.2; nitrogen-free extract, 92.4; crude fiber, 19.0; crude protein, 68.7; and ether extract, 76.4.

On comparing the coefficients of the nutrients of this ration with those of wheat flour middlings when fed alone, it will be noted that the dry substance, the nitrogen-free extract, and the crude fiber of the tankage and corn were digested much more thoroly than those of the wheat flour middlings alone, while the crude protein was digested decidedly less thoroly. The coefficients of digestibility of the ether extract were practically the same in the two rations.

A comparison of the coefficients of the nutrients of this ration with those of the ration of ground corn fed alone shows that the dry substance, the crude protein, and the nitrogen-free extract of the tankage and corn were digested practically to the same extent as those of the ground corn alone, while the ether extract and the crude fiber of the tankage and corn were digested much more thoroly than those of the ground corn alone.

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[1] Dietrich and Grindley: Ill. Agr. Exp. Sta. Bul. 170.

TABLE 4.—COEFFICIENTS OF DIGESTIBILITY

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
First Test Period. December 18 to 27, 1913. Ten days. Middlings					
113	75.3	83.5	21.5	78.7	82.0
213	73.7	82.3	20.3	77.5	77.7
313	76.1	83.8	23.9	80.5	83.0
413	74.9	82.7	25.5	77.9	80.7
Average	75.0	83.1	22.8	78.7	80.9
Second Test Period. December 28, 1913 to January 6, 1914. Ten Days. Middlings					
113	75.3	82.6	22.3	80.1	87.2
213	74.2	81.7	19.6	79.6	82.5
313	74.4	81.3	14.9	82.5	85.8
413	73.4	79.7	34.1	77.6	79.6
Average	74.3	81.3	22.7	80.0	83.8
Third Test Period. January 24 to February 2, 1914. Ten days. Middlings and ground corn (1 to 1)					
113	79.1	85.5	19.2	78.2	78.3
213	78.8	85.4	22.1	76.5	78.6
313	80.3	86.7	12.0	81.6	87.4
413	79.6	86.7	13.0	75.1	88.2
Average	79.5	86.1	16.6	77.9	83.1
Fourth Test Period. February 3 to 12, 1914. Ten days. Middlings and ground corn (1 to 1)					
113	78.5	86.3	0.2	78.1	77.9
213	79.0	85.5	17.5	76.4	84.1
313	79.0	86.1	3.0	78.2	87.0
413	78.3	85.4	9.6	74.0	86.1
Average	78.7	85.8	7.6	76.7	83.8
Fifth Test Period. March 7 to 17, 1914. Ten days. Ground corn					
113	88.7	93.1	27.2	76.8	83.2
213	86.6	92.5	21.4	71.7	57.3
313	88.2	92.4	40.1	76.2	79.2
413	88.5	93.5	29.9	76.5	63.4
Average	88.0	92.9	29.7	75.3	70.8
Sixth Test Period. March 18 to 27, 1914. Ten days. Ground corn					
113	88.0	92.2	34.2	77.1	82.3
213	86.3	92.0	20.3	70.8	64.8
313	88.9	93.4	42.9	76.3	72.1
413	87.4	92.2	30.4	74.9	70.8
Average	87.7	92.5	32.0	74.8	72.5

TABLE 4.—*Concluded*

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
Seventh Test Period. April 26 to May 5, 1914. Ten days. Middlings					
113	73.3	79.8	15.5	79.5	89.0
213	73.2	78.5	26.0	79.1	88.5
313	74.9	80.1	18.3	83.3	87.8
413	72.1	78.4	15.3	78.4	85.8
Average	73.4	79.2	18.8	80.1	87.8
Eighth Test Period. May 6 to 15, 1914. Ten days. Middlings					
113	75.4	82.0	18.1	80.8	92.8
213	74.7	80.9	19.5	80.7	89.7
313	74.8	81.1	19.8	82.6	88.1
413	74.9	81.2	21.0	80.2	86.7
Average	75.0	81.3	19.6	81.1	89.3
Ninth Test Period. June 5 to 14, 1914. Ten days. Tankage and ground corn (1 to 7.5)					
113	87.3	92.6	49.9	78.1	86.7
213	86.0	92.1	41.1	73.1	87.7
313	87.5	93.3	53.9	75.0	92.3
413	85.5	91.5	44.7	73.9	80.1
Average	86.6	92.4	47.4	75.0	86.7
Tenth Test Period. June 15 to 24, 1914. Ten days. Tankage and ground corn (1 to 7.5)					
113	86.7	92.2	52.8	76.9	86.6
213	85.4	91.5	49.2	73.1	82.6
313	88.5	94.0	60.4	77.0	87.6
413	87.1	92.8	54.6	75.2	83.0
Average	86.9	92.6	54.3	75.6	85.0

THE INFLUENCE OF ONE FEED UPON THE DIGESTIBILITY OF THE NUTRIENTS OF ANOTHER FEED

The doubtful values obtained in digestion experiments in our previous work and in the work of others, by determining indirectly, or by calculation, the coefficients of the nutrients for one feed by subtracting the weights of the digestible nutrients of another feed from the corresponding values for the two feeds combined, led us to plan these experiments to determine more accurately, if possible, the influence of one feed upon the digestibility of the nutrients of another feed.

From the results of practical feeding experiments some authors have taken the view that when feeds are fed singly, they are not as completely digested as when fed in mixed rations, because rations composed of a single feed are not as efficient for producing growth and fattening as mixed feeds. For example, whenever milk is added to a

TABLE 5.—SUMMARY OF THE AVERAGE COEFFICIENTS OF DIGESTIBILITY OF THE RATIONS

	Period	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
Wheat flour middlings	1	75.0	83.1	22.8	78.7	80.9
Wheat flour middlings	2	74.3	81.3	22.7	80.0	83.8
Average	..	74.6	82.2	22.7	79.3	82.3
Wheat flour middlings	7	73.4	79.2	18.8	80.1	87.8
Wheat flour middlings	8	75.0	81.3	19.6	81.1	89.3
Average	..	74.2	80.2	19.2	80.6	88.5
Ground corn and middlings	3	79.5	86.1	16.6	77.9	83.1
Ground corn and middlings	4	78.7	85.8	7.6	76.7	83.8
Average	..	79.1	85.9	12.1	77.3	83.4
Ground corn	5	88.0	92.9	29.7	75.3	70.8
Ground corn	6	87.7	92.5	32.0	74.8	72.5
Average	..	87.8	92.7	30.8	75.0	71.6
Tankage and ground corn	9	86.6	92.4	47.4	75.0	86.7
Tankage and ground corn	10	86.9	92.8	54.3	75.6	85.0
Average	..	86.7	92.6	50.8	75.3	85.8

ration composed of a single grain, a larger amount of pork is produced than when the same amount of nutrients from the single grain is fed. It has therefore been assumed by some authors that in such cases the increased production is due to the fact that the milk increased the digestibility of the grains with which it was fed. However, it has recently been proved that there are other factors that favor increased production where the mixed rations are fed.

The data for the coefficients of digestibility of the nutrients of the wheat flour middlings, as determined directly when fed alone, and as calculated indirectly from the results of direct digestion experiments with the ration of middlings and ground corn and of the ground corn alone, are given in Table 6. It will be noted that the individual data and the average data for the four pigs show that the calculated values indirectly determined for the coefficients of digestibility of the dry substance and the nitrogen-free extract of the middlings are significantly lower than the corresponding coefficients of the nutrients of the middlings determined directly by the digestion experiments.

The results indicate that there is no significant difference between the coefficients for the protein as calculated indirectly and as determined directly. The results for the ether extract are very irregular, but the average results indicate that the calculated values for the coefficients of the ether extract for the middlings are probably significantly higher than those determined directly by actual experiments. It is quite apparent from the experimental data here presented that the calculated coefficients for the crude fiber are very irregular as compared with those determined directly.

TABLE 6.—COEFFICIENTS OF DIGESTIBILITY OF MIDDLINGS, DIRECTLY AND INDIRECTLY DETERMINED

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
Middlings fed alone. First Test Period					
113	75.3	83.5	21.5	78.7	82.0
213	73.7	82.3	20.3	77.5	77.7
313	76.1	83.8	23.9	80.5	83.0
413	74.9	82.7	25.5	77.9	80.7
Average	75.0	83.1	22.8	78.7	80.8
Middlings calculated from middlings and corn ration. Third and Fifth Test Periods					
113	69.9	75.6	16.6	78.9	75.9
213	71.4	76.1	22.4	78.7	89.0
313	72.2	79.3	3.0	84.1	91.4
413	71.1	77.7	7.6	74.4	100.3
Average	71.2	77.2	12.4	79.0	89.2
Middlings fed alone. Second Test Period					
113	75.3	82.6	22.3	80.1	87.2
213	74.2	81.7	19.6	79.6	82.5
313	74.4	81.3	14.9	82.5	85.4
413	73.4	79.7	34.1	77.6	79.6
Average	74.3	81.3	22.7	79.9	83.7
Middlings calculated from middlings and corn ration. Fourth and Sixth Test Periods					
113	69.5	78.8	−10.7	78.5	75.9
213	71.9	76.9	16.7	79.0	93.6
313	69.5	76.5	−9.8	79.1	94.3
413	69.8	76.6	2.9	73.5	93.6
Average	70.2	77.2	−0.2	77.5	89.3

The data for the coefficients of digestibility of the nutrients of the ground corn as determined directly when fed alone, and as calculated indirectly from the direct experiments with the combined ration composed of middlings and ground corn and the wheat flour middlings alone, are given in Table 7. A study of these data leads in general to the same conclusions as to the variations and differences between the direct and indirect coefficients of the nutrients of the ground corn as were reached with regard to the direct and indirect values for wheat flour middlings. It should be said, however, that the calculated coefficients for the crude fiber and the ether extract of the corn are more irregular than the corresponding calculated coefficients for the wheat flour middlings.

The data for the coefficients of digestibility of the nutrients of the ration composed of one part of middlings and one part of ground corn, as determined directly, and as calculated indirectly from the coefficients directly determined for middlings when fed alone and for ground corn when fed alone, are given in Table 8. It is apparent that the calculated coefficients for the ether extract of the ration are lower than those directly determined for the mixed ration. There is apparently no significant difference between the calculated coefficients and the directly determined coefficients for the protein of the mixed ration.

It is thus evident from the individual data, as well as from the average results given in Tables 6 to 8, inclusive, that the digestibility of the nutrients of a ration composed of equal parts of wheat flour middlings and ground corn are not what they would be if the coefficients of digestibility of the nutrients of each of the feeds when fed together had remained the same as they were in the individual feeds when fed alone. This difference between the directly and indirectly

TABLE 7.—COEFFICIENTS OF DIGESTIBILITY OF GROUND CORN, DIRECTLY AND INDIRECTLY DETERMINED

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
Ground corn fed alone. Fifth Test Period					
113	88.7	93.1	27.2	76.8	83.2
213	86.6	92.5	21.4	71.7	57.3
313	88.2	92.4	40.1	76.2	79.2
413	88.5	93.5	29.9	76.5	63.4
Average	88.0	92.9	29.6	75.3	70.8
Ground corn calculated from middlings and corn ration. First and Third Test Periods					
113	83.0	87.1	12.0	77.4	70.8
213	84.2	87.7	27.7	74.5	80.4
313	84.8	89.0	–25.3	83.9	96.5
413	84.5	89.7	–26.0	69.0	103.6
Average	84.1	88.4	–2.9	76.2	87.8
Ground corn fed alone. Sixth Test Period					
113	88.0	92.2	34.2	77.1	82.3
213	86.3	92.0	20.3	70.8	64.8
313	88.9	93.4	42.9	76.3	72.1
413	87.4	92.2	30.4	74.9	70.8
Average	87.6	92.4	31.9	74.8	72.5
Ground corn calculated from middlings and corn ration. Second and Fourth Test Periods					
113	81.9	89.2	–69.0	73.9	58.8
213	84.0	88.4	11.2	69.6	87.6
313	83.7	89.7	–34.2	69.6	89.0
413	83.4	89.8	–67.0	66.2	99.5
Average	83.3	89.3	–39.8	69.8	83.7

TABLE 8.—COEFFICIENTS OF DIGESTIBILITY OF A RATION OF MIDDLINGS AND GROUND CORN (1 TO 1), DIRECTLY AND INDIRECTLY DETERMINED

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
Middlings and ground corn (1 to 1) fed together, direct determination. Third Test Period					
113	79.1	85.5	19.2	78.2	78.3
213	78.8	85.4	22.1	76.5	78.6
313	80.3	86.7	12.0	81.6	87.4
413	79.6	86.7	13.0	75.1	88.2
Average	79.5	86.1	16.6	77.9	83.1
Middlings and ground corn (1 to 1) calculated from the direct determinations of the middlings ration and the corn ration. First and Fifth Test Periods					
113	81.9	88.9	22.9	78.1	82.4
213	80.0	88.1	20.6	75.7	70.9
313	82.0	88.7	27.9	79.1	81.7
413	81.6	88.8	26.6	77.5	74.9
Average	81.4	88.6	24.5	77.6	77.5
Middlings and ground corn (1 to 1) calculated from the indirect determinations for the corn ration and the middlings ration (see second sections of Tables 6 and 7)					
113	76.3	82.1	15.5	78.4	74.2
213	77.7	82.7	23.7	77.4	86.1
313	78.4	84.8	−4.0	84.0	93.1
413	77.7	84.5	−0.7	72.7	101.4
Average	77.5	83.5	8.6	78.1	88.7
Middlings and ground corn (1 to 1) fed together, direct determination. Fourth Test Period					
113	78.5	86.3	0.2	78.1	77.9
213	79.0	85.5	17.6	76.4	84.1
313	79.0	86.1	3.0	78.2	87.0
413	78.3	85.4	9.6	74.0	86.1
Average	78.7	85.8	7.6	76.7	83.8
Middlings and ground corn (1 to 1) calculated from the direct determinations of the corn ration and the middlings ration. Second and Sixth Test Periods					
113	81.5	88.0	25.2	79.2	85.6
213	80.1	87.5	19.8	76.8	76.6
313	81.5	88.2	21.8	80.5	81.2
413	80.3	86.8	33.2	76.7	76.6
Average	80.8	87.6	25.0	78.3	80.0
Middlings and ground corn (1 to 1) calculated from the indirect determinations for the corn ration and the middlings ration (see fourth sections of Tables 6 and 7)					
113	75.6	84.7	−25.1	77.0	70.2
213	77.8	83.4	15.3	76.0	91.6
313	76.5	84.0	−15.8	75.9	92.5
413	76.5	84.1	−14.4	71.2	95.6
Average	76.6	84.0	−10.0	75.0	87.5

determined coefficients of the nutrients of the mixed ration may be due to one or the other of the following influences: First, it is possible that either the wheat flour middlings or the ground corn in the mixed ration influences directly the digestibility of the nutrients of the other feed. Second, it is possible, on the other hand, that there is a mutual influence of each feed upon the other, which results in decreasing the digestibility of the dry substance, the nitrogen-free extract, and the crude fiber; and in increasing the digestibility of the ether extract of the mixed ration.

INDIVIDUALITY OF PIGS AS TO THE THORONESS WITH WHICH THEY DIGEST THEIR FEED

From the preceding results it was possible to study the question of the individuality of pigs as to the thoroness with which they digest their feed. The influence of the individual peculiarities of experimental animals upon the thoroness of digestion of their feed is a matter of considerable interest. Very often when the same ration is fed to three or more animals of the same species, as many different coefficients of digestibility are obtained for the same nutrient as there are animals. The variations are usually not great, but they nearly always occur, and the question arises as to the part which the factor of individuality plays in producing these variations.

The data for the coefficients of digestibility of the crude protein obtained in forty digestion trials, of ten days each, in which four rations were fed to each of four pigs, are given in Table 9. Examination of the data shows that the individual coefficients for Pig 313 are significantly greater than the individual coefficients for Pig 213, in each of the ten experimental periods. A similar comparison of the coefficients of digestibility of protein for Pigs 313 and 413 shows a similar significant difference. Since conditions thruout the experiment were practically identical, the data lead clearly to the conclusion that, altho the pigs were litter mates and were fed together from birth, individuality was shown by a distinct and well-defined difference between the coefficients of digestibility of crude protein for Pig 313 and Pigs 213 and 413 thruout the ten experiments. A further study of the data in this table shows that for Pigs 113 and 213 and for Pigs 113 and 413 there was a considerable, tho less marked, difference in the coefficients of digestibility of crude protein which apparently can be assigned to the factor of individuality; but that there are practically no differences in the coefficients of digestibility of crude protein for Pigs 213 and 413 or for Pigs 113 and 313, that can be considered as due to the factor of individuality.

Examination of the data given in Table 9 for the coefficients of the dry matter, the nitrogen-free extract, and the ether extract shows in general the same individual differences as were found in the coeffi-

TABLE 9.—SUMMARY OF THE COEFFICIENTS OF DIGESTIBILITY OF THE NUTRIENTS SHOWING THE INDIVIDUALITY OF PIGS AS TO THE THORONESS WITH WHICH THEY DIGESTED THEIR FEED

Period	Ration	Pig 313	Pig 113	Pig 413	Pig 213	Pig 313	Pig 113	Pig 413	Pig 213
		Crude protein				Ether extract			
1	Middlings (alone)............	80.5	78.7	77.9	77.5	83.0	82.0	80.7	77.7
2	Middlings (alone)............	82.5	80.1	77.6	79.6	85.8	87.2	79.6	82.5
7	Middlings (alone)............	83.3	79.5	78.4	79.1	87.8	89.0	85.8	88.5
8	Middlings (alone)............	82.6	80.8	80.2	80.7	88.1	92.8	86.7	89.7
3	Middlings and corn (1 to 1)...	81.6	78.2	75.1	76.5	87.4	78.3	88.2	78.6
4	Middlings and corn (1 to 1)...	78.2	78.1	74.0	76.4	87.0	77.9	86.1	84.1
5	Corn (alone).................	76.2	76.8	76.5	71.7	79.2	83.2	63.4	57.3
6	Corn (alone).................	76.3	77.1	74.9	70.8	72.1	82.3	70.8	64.8
9	Tankage and corn (1 to 7.5)....	75.0	78.1	73.9	73.1	92.3	86.7	80.1	87.7
10	Tankage and corn (1 to 7.5)....	77.0	76.9	75.2	73.1	87.6	86.6	83.0	82.6
	Average..................	79.3	78.4	76.4	75.8	85.0	84.6	80.4	79.3
		Dry substance				Nitrogen-free extract			
1	Middlings (alone)............	76.1	75.3	74.9	73.7	83.8	83.5	82.7	82.3
2	Middlings (alone)............	74.4	75.3	73.4	74.2	81.3	82.6	79.7	81.7
7	Middlings (alone)............	74.9	73.3	72.1	73.2	80.1	79.8	78.4	78.5
8	Middlings (alone)............	74.8	75.4	74.9	74.7	81.1	82.0	81.2	80.9
3	Middlings and corn (1 to 1)...	80.3	79.1	79.6	78.8	86.7	85.5	86.7	85.4
4	Middlings and corn (1 to 1)...	79.0	78.5	78.3	79.0	86.1	86.3	85.4	85.5
5	Corn (alone).................	88.2	88.7	88.5	86.6	92.4	93.1	93.5	92.5
6	Corn (alone).................	88.9	88.0	87.4	86.3	93.4	92.2	92.2	92.0
9	Tankage and corn (1 to 7.5)....	87.5	87.3	85.5	86.0	93.5	92.8	91.7	92.4
10	Tankage and corn (1 to 7.5)....	88.5	86.7	87.1	85.4	94.2	92.5	93.1	91.8
	Average..................	81.3	80.8	80.2	79.8	87.3	87.0	86.5	86.3

cients of digestibility of the crude protein for the four pigs. However, the individuality of these pigs with reference to their power of digesting dry matter, nitrogen-free extract, and ether extract is not so clearly evident as it was in the case of crude protein.

It is apparent, therefore, that in this series of experiments, all with the same animals, in which different rations were used in the different experiments, the coefficients as a whole showed constantly higher values for some animals than for other animals. Such consistent differences under such conditions must be attributed to the individuality of the different animals.

The total gains in weight of the four pigs during the ten experimental periods, each of ten days' duration, during which time each of the four animals received the same kinds of feed and the same quantities of feed per 100 pounds of live weight, were as follows: Pig 113, 79 pounds; Pig 213, 74 pounds; Pig 313, 57 pounds; and Pig 413, 65 pounds. The average live weights of the pigs during the ten experimental periods were as follows: Pig 113, 250.5 pounds; Pig 213, 250.8 pounds; Pig 313, 214.3 pounds; and Pig 413, 211.0 pounds. The weights of the total feeds consumed during this same time were as follows: Pig 113, 503.2 pounds; Pig 213, 503.2 pounds; Pig 313, 423.2 pounds; and Pig 413, 423.2 pounds. The weights of feed required to produce 100 pounds of gain during the ten experimental periods were as follows: Pig 113, 637 pounds; Pig 213, 680 pounds; Pig 313, 743 pounds; and Pig 413, 651 pounds. Comparing these gains in weight and the economy of the gains in weight with the average coefficients of digestibility of the nutrients of the feeds for each animal, it will be noted that there is no consistent correlation between the coefficients of digestibility and the gains, or the economy of gains, in weight. For example, Pig 113, which on the average digested all of the nutrients of the feeds more thoroly than did Pig 213 (which weighed the same and consumed an equal quantity of the same feeds as Pig 113) made a gain of 79 pounds and required 637 pounds of feed to produce 100 pounds of gain; while Pig 213 gained 74 pounds and required 680 pounds of feed to produce 100 pounds of gain. On the other hand, Pig 313, which on the average digested all of the nutrients of the feeds more thoroly than did Pig 413 (which weighed the same and consumed an equal quantity of the same feeds as Pig 313) made a gain of only 57 pounds and required 743 pounds of feed to produce 100 pounds of gain; while Pig 413 gained 65 pounds and required 651 pounds of feed to produce 100 pounds of gain.

This study clearly shows that different animals of the same species may show individuality as to the thoroness with which they digest the nutrients of their feeds. However, such differences in the coefficients of digestibility of the nutrients of the same feeds by different animals are probably too small to be considered of practical or economic importance.

SECOND SERIES OF EXPERIMENTS, 1914-1915

PLAN

Four cross-bred Duroc Jersey-Poland China barrows of the same age as the pigs used in the first series of experiments—namely, a few days over seven months, and all from the same litter—were selected for this second series of experiments. The pens, feed troughs, and digestion harness were the same as those used in the first experiments. In the second series ground barley (malting) was substituted for the wheat flour middlings used in the first series, but the ratio of feed to the live weight of the animals, the length of the transitional, the preliminary, and the test periods, and the general management and treatment of the animals were the same. The weather conditions during the two series of experiments were also similar.

The first ration for which the coefficients of digestibility were determined consisted of 2.08 pounds of ground barley (malting) per 100 pounds live weight; the second, of 1.05 pounds of ground barley and 1.05 pounds of ground corn (No. 2 yellow) per 100 pounds live weight; the third, of 2.12 pounds of ground corn per 100 pounds live weight; and the fourth, of 1.80 pounds of ground corn and 0.24 pounds of digester tankage per 100 pounds live weight. Each of these rations was fed for two ten-day periods, during which time samples of the feeds and the feces were taken for chemical analysis.

CHEMICAL COMPOSITION OF FEEDS AND FECES; AND WEIGHTS OF PIGS, FEEDS, WATER, FECES, AND URINE

The chemical composition of the feeds and the fresh feces are given in Tables 10 and 12, respectively. The weights of the pigs, the feeds, the water, the feces, and the urine are presented in Table 11.

From the experimental data given in Table 11, it will be noted that the weights of the feces per pound of feed varied markedly depending upon the character of the ration. Thus the average weights of the fresh feces per pound of feed were as follows: in Periods 1 and 2, in which ground barley was fed, 0.96 pound; in Periods 3 and 4, in which ground barley and ground corn in the ratio of 1 to 1 were fed, 0.68 pound; in Periods 7 and 8, in which tankage and ground corn in the ratio of 1 to 7.5 were fed, 0.41 pound; and in Periods 5 and 6, in which ground corn was fed, 0.36 pound.

Examination of the data of Table 12, giving the composition of the fresh feces, and of Table 13, showing the coefficients of digestibility of the nutrients of the rations, shows that the differences mentioned above in the weights of the feces per pound of feed due to the character of the ration consumed can be traced, in large part at least, as in the first experiments, to the variations in the water content of the feces, and to the variations in the coefficients of digestibility of the dry substance of the rations. Thus, the average water content of the feces for the several periods was as follows: Periods 1 and 2, in which ground barley alone was fed, 72.20 percent; Periods 3 and 4, in which ground barley and ground corn in the ratio of 1 to 1 were fed, 74.91 percent; Periods 7 and 8, in which tankage and ground corn in the ratio of 1 to 7.5 were fed, 68.81 percent; and Periods 5 and 6, in which ground corn alone was fed, 67.74 percent. The average coefficients of

TABLE 10.—CHEMICAL COMPOSITION OF THE FEEDS

(Results expressed in percent of the fresh substance)

Kind of feed	Used in periods	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract	Crude ash	Total nitrogen
Ground corn..	3, 4	86.32	69.85	3.73	9.51	3.73	1.17	1.522
Ground corn..	5, 6	83.94	68.17	2.06	9.15	3.37	1.18	1.464
Ground corn..	7, 8	86.22	71.37	2.29	9.31	2.06	1.19	1.489
Average....		85.49	69.80	2.69	9.32	3.05	1.18	1.492
Barley.......	1, 2	91.00	67.06	4.02	14.80	2.35	2.77	2.368
Barley.......	3, 4	91.07	70.04	4.96	11.29	2.14	2.65	1.806
Average....		91.03	68.55	4.49	13.04	2.24	2.71	2.087
Tankage.....	7, 8	88.65	12.51	5.33	58.53	8.15	15.49	9.364

TABLE 11.—WEIGHTS OF PIGS, FEEDS, WATER, FECES, AND URINE
(Results expressed in pounds)

<table>
<tr><th rowspan="2">Pig</th><th rowspan="2">Live weight</th><th colspan="4">Feeds consumed</th><th rowspan="2">Water</th><th rowspan="2">Total feces</th><th rowspan="2">Feces per lb. of feed</th><th rowspan="2">Total urine</th></tr>
<tr><th>Barley</th><th>Ground corn</th><th>Total</th><th>Per day per 100 lbs. live weight</th></tr>
<tr><td colspan="10">First Test Period. November 27 to December 6, 1914. Ten days. Barley</td></tr>
<tr><td>114</td><td>217.1</td><td>45.00</td><td>.....</td><td>45.00</td><td>2.07</td><td>143.40</td><td>39.01</td><td>0.87</td><td>100.76</td></tr>
<tr><td>214</td><td>182.4</td><td>38.40</td><td>.....</td><td>38.40</td><td>2.11</td><td>122.40</td><td>36.23</td><td>0.94</td><td>83.41</td></tr>
<tr><td>314</td><td>174.1</td><td>37.40</td><td>.....</td><td>37.40</td><td>2.15</td><td>119.00</td><td>35.33</td><td>0.94</td><td>80.12</td></tr>
<tr><td>414</td><td>158.9</td><td>33.00</td><td>.....</td><td>33.00</td><td>2.08</td><td>105.00</td><td>32.17</td><td>0.97</td><td>68.39</td></tr>
<tr><td>Average</td><td>183.1</td><td>38.45</td><td>.....</td><td>38.45</td><td>2.10</td><td>122.45</td><td>35.68</td><td>0.93</td><td>83.17</td></tr>
<tr><td colspan="10">Second Test Period. December 7 to 16, 1914. Ten days. Barley</td></tr>
<tr><td>114</td><td>222.9</td><td>45.00</td><td>.....</td><td>45.00</td><td>2.02</td><td>143.40</td><td>41.92</td><td>0.93</td><td>106.27</td></tr>
<tr><td>214</td><td>187.4</td><td>38.40</td><td>.....</td><td>38.40</td><td>2.05</td><td>122.40</td><td>37.07</td><td>0.97</td><td>86.00</td></tr>
<tr><td>314</td><td>177.9</td><td>37.40</td><td>.....</td><td>37.40</td><td>2.10</td><td>119.00</td><td>37.42</td><td>1.00</td><td>74.54</td></tr>
<tr><td>414</td><td>162.4</td><td>33.00</td><td>.....</td><td>33.00</td><td>2.03</td><td>105.00</td><td>34.99</td><td>1.06</td><td>67.97</td></tr>
<tr><td>Average</td><td>187.6</td><td>38.45</td><td>.....</td><td>38.45</td><td>2.05</td><td>122.45</td><td>37.85</td><td>0.99</td><td>83.69</td></tr>
<tr><td colspan="10">Third Test Period. January 17 to 26, 1915. Ten days. Barley and ground corn (1 to 1)</td></tr>
<tr><td>114</td><td>242.6</td><td>26.00</td><td>26.00</td><td>52.00</td><td>2.14</td><td>164.00</td><td>33.60</td><td>0.65</td><td>133.64</td></tr>
<tr><td>214</td><td>203.6</td><td>21.50</td><td>21.50</td><td>43.00</td><td>2.11</td><td>136.00</td><td>30.31</td><td>0.71</td><td>108.01</td></tr>
<tr><td>314</td><td>190.9</td><td>20.00</td><td>20.00</td><td>40.00</td><td>2.10</td><td>130.00</td><td>27.05</td><td>0.68</td><td>99.57</td></tr>
<tr><td>414</td><td>173.4</td><td>18.50</td><td>18.50</td><td>37.00</td><td>2.13</td><td>116.00</td><td>26.26</td><td>0.71</td><td>86.99</td></tr>
<tr><td>Average</td><td>202.6</td><td>21.50</td><td>21.50</td><td>43.00</td><td>2.12</td><td>136.50</td><td>29.30</td><td>0.69</td><td>107.05</td></tr>
<tr><td colspan="10">Fourth Test Period. January 27 to February 5, 1915. Ten days. Barley and ground corn (1 to 1)</td></tr>
<tr><td>114</td><td>247.6</td><td>26.00</td><td>26.00</td><td>52.00</td><td>2.10</td><td>164.00</td><td>31.96</td><td>0.62</td><td>132.65</td></tr>
<tr><td>214</td><td>207.4</td><td>21.50</td><td>21.50</td><td>43.00</td><td>2.07</td><td>136.00</td><td>28.77</td><td>0.67</td><td>108.45</td></tr>
<tr><td>314</td><td>195.6</td><td>20.00</td><td>20.00</td><td>40.00</td><td>2.04</td><td>130.00</td><td>26.22</td><td>0.66</td><td>100.16</td></tr>
<tr><td>414</td><td>177.1</td><td>18.50</td><td>18.50</td><td>37.00</td><td>2.09</td><td>116.00</td><td>26.94</td><td>0.73</td><td>87.68</td></tr>
<tr><td>Average</td><td>206.9</td><td>21.50</td><td>21.50</td><td>43.00</td><td>2.07</td><td>136.50</td><td>28.47</td><td>0.67</td><td>107.23</td></tr>
<tr><td colspan="10">Fifth Test Period. March 6 to 15, 1915. Ten days. Ground corn</td></tr>
<tr><td>114</td><td>280.9</td><td>.....</td><td>60.00</td><td>60.00</td><td>2.14</td><td>194.00</td><td>20.47</td><td>0.34</td><td>170.82</td></tr>
<tr><td>214</td><td>230.9</td><td>.....</td><td>48.60</td><td>48.60</td><td>2.10</td><td>158.00</td><td>17.38</td><td>0.36</td><td>139.98</td></tr>
<tr><td>314</td><td>218.1</td><td>.....</td><td>47.60</td><td>47.60</td><td>2.18</td><td>156.00</td><td>17.16</td><td>0.36</td><td>135.55</td></tr>
<tr><td>414</td><td>201.1</td><td>.....</td><td>43.80</td><td>43.80</td><td>2.18</td><td>142.00</td><td>17.45</td><td>0.40</td><td>118.51</td></tr>
<tr><td>Average</td><td>232.7</td><td>.....</td><td>50.00</td><td>50.00</td><td>2.15</td><td>162.50</td><td>18.11</td><td>0.36</td><td>141.21</td></tr>
</table>

TABLE 11.—*Concluded*

Pig	Live weight	Feeds consumed				Water	Total feces	Feces per lb. of feed	Total urine
		Tankage	Ground corn	Total	Per day per 100 lbs. live weight				
Sixth Test Period. March 16 to 25, 1915. Ten days. Ground corn									
114	290.1	.....	60.00	60.00	2.07	194.00	21.35	0.36	172.29
214	239.1	.....	48.60	48.60	2.03	158.00	15.72	0.32	140.30
314	225.6	.....	47.60	47.60	2.11	156.00	16.69	0.35	132.43
414	207.6	.....	43.80	43.80	2.11	142.00	17.04	0.39	117.51
Average	240.6	.....	50.00	50.00	2.08	162.50	17.70	0.37	140.63
Seventh Test Period. April 22 to May 1, 1915. Ten days. Tankage and ground corn (1 to 7.5)									
114	352.6	8.54	64.06	72.60	2.06	220.00	30.84	0.42	173.22
214	286.9	6.87	51.53	58.40	2.04	182.00	21.43	0.37	139.52
314	275.6	6.70	50.30	57.00	2.07	178.00	22.97	0.40	130.58
414	256.1	6.35	47.65	54.00	2.11	172.00	21.40	0.40	133.61
Average	292.8	7.11	53.38	60.50	2.07	188.00	24.16	0.40	144.23
Eighth Test Period. May 2 to 11, 1915. Ten days. Tankage and ground corn (1 to 7.5)									
114	366.4	8.54	64.06	72.60	1.98	220.00	30.47	0.42	173.22
214	300.6	6.87	51.53	58.40	1.94	182.00	21.76	0.37	153.09
314	288.4	6.70	50.30	57.00	1.98	178.00	26.07	0.46	146.16
414	267.4	6.35	47.65	54.00	2.02	172.00	23.71	0.44	141.06
Average	305.7	7.11	53.38	60.50	1.98	188.00	25.50	0.42	153.38

digestibility of the dry substance of the rations for the several periods were as follows: Periods 1 and 2, in which ground barley alone was fed, 70.8; Periods 3 and 4, in which ground barley and ground corn in the ratio of 1 to 1 were fed, 80.9; Periods 7 and 8, in which tankage and ground corn in the ratio of 1 to 7.5 were fed, 85.3; and Periods 5 and 6, in which ground corn alone was fed, 86.2.

COEFFICIENTS OF DIGESTIBILITY OF THE NUTRIENTS OF THE RATIONS

The coefficients of digestibility of the nutrients of the rations for the four pigs, as determined directly, for the eight experimental periods of this series of experiments are given in Tables 13 and 14.

Ground Barley.—It is evident from Table 13 that the coefficients of digestibility of the nutrients for ground barley, when fed alone in Periods 1 and 2, varied for the different animals during the same experimental period. This is especially true of the coefficients for the crude fiber and the ether extract. It is also evident that the coefficients varied considerably for the same animal in different periods.

TABLE 12.—CHEMICAL COMPOSITION OF THE FECES
(Results expressed in percent of fresh substance)

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract	Crude ash	Total nitrogen
First Test Period. November 27 to December 6, 1914. Ten days. Barley							
114	27.86	14.03	3.67	6.77	0.95	2.45	1.083
214	27.86	13.43	3.66	6.69	1.82	2.26	1.070
314	29.13	13.94	3.59	7.58	1.79	2.24	1.213
414	26.81	11.79	3.88	7.13	1.83	2.18	1.141
Average	27.92	13.30	3.70	7.04	1.60	2.28	1.127
Second Test Period. December 7 to 16, 1914. Ten days. Barley							
114	25.25	10.94	3.88	7.08	0.89	2.46	1.132
214	28.30	13.69	3.85	6.63	1.90	2.24	1.060
314	29.34	14.01	3.65	7.66	1.81	2.21	1.222
414	27.82	13.49	3.08	7.14	1.99	2.12	1.143
Average	27.68	13.03	3.62	7.13	1.65	2.26	1.139
Third Test Period. January 17 to 26, 1915. Ten days. Barley and ground corn (1 to 1)							
114	24.97	11.97	4.41	4.82	0.88	2.45	0.771
214	24.16	11.52	4.48	4.85	0.99	2.31	0.776
314	24.95	10.86	5.12	5.15	1.47	2.35	0.824
414	23.15	10.21	4.34	5.29	1.13	2.18	0.846
Average	24.30	11.14	4.59	5.03	1.12	2.32	0.804
Fourth Test Period. January 27 to February 5, 1915. Ten days. Barley and ground corn (1 to 1)							
114	25.80	11.93	4.67	5.10	1.66	2.44	0.816
214	25.86	12.34	4.31	5.37	1.22	2.61	0.859
314	27.02	12.68	4.25	5.47	2.25	2.37	0.875
414	24.80	11.18	4.41	5.22	1.79	2.19	0.835
Average	25.87	12.03	4.41	5.29	1.73	2.40	0.846
Fifth Test Period. March 6 to 15, 1915. Ten days. Ground corn							
114	31.59	16.26	3.62	6.77	2.15	2.79	1.083
214	31.94	16.76	3.41	6.49	2.62	2.66	1.012
314	33.27	16.65	3.52	6.86	3.71	2.56	1.098
414	31.10	15.35	3.49	6.23	3.52	2.52	0.997
Average	31.98	16.26	3.51	6.59	3.00	2.63	1.048
Sixth Test Period. March 16 to 25, 1915. Ten days. Ground corn							
114	32.64	16.03	3.58	6.99	3.33	2.72	1.118
214	32.04	16.90	3.50	6.38	2.54	2.72	1.020
314	33.66	16.26	3.52	7.01	4.12	2.75	1.121
414	31.80	15.32	3.44	6.31	4.16	2.56	1.010
Average	32.54	16.13	3.51	6.67	3.54	2.69	1.067

TABLE 12.—*Concluded*

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract	Crude ash	Total nitrogen
Seventh Test Period. April 22 to May 1, 1915. Ten days. Tankage and ground corn (1 to 7.5)							
114	32.39	13.24	3.20	9.78	1.73	4.42	1.565
214	30.28	12.17	2.93	9.80	1.81	3.58	1.568
314	31.67	13.33	3.24	9.23	2.13	3.74	1.476
414	32.85	14.26	3.27	9.76	1.45	4.11	1.561
Average	31.80	13.25	3.16	9.64	1.78	3.96	1.543
Eighth Test Period. May 2 to 11, 1915. Ten days. Tankage and ground corn (1 to 7.5)							
114	27.90	10.03	3.10	9.28	1.19	4.31	1.484
214	29.87	12.14	2.85	9.68	1.19	4.02	1.548
314	32.14	14.18	3.15	9.12	1.78	3.93	1.459
414	32.40	14.09	3.30	9.27	1.82	3.89	1.483
Average	30.58	12.61	3.10	9.34	1.50	4.04	1.494

The average coefficients of digestibility of the nutrients of ground barley when fed alone to the four pigs for the two ten-day periods (eight digestion trials) were as follows: dry substance, 70.8; nitrogen-free extract, 81.2; crude fiber, 14.1; crude protein, 54.0; and ether extract, 33.0. Ground barley was the least digestible of any of the rations used in this experiment. The coefficients of digestibility of the crude protein, the ether extract, and the crude fiber were very low.

Ground Corn.—The coefficients of digestibility of the nutrients of ground corn fed alone in Periods 5 and 6 varied somewhat for the different pigs during the same period. The average coefficients of digestibility of all the nutrients, except those of the ether extract, agreed very closely for the two periods.

The average coefficients of digestibility of the nutrients of the ground corn when fed alone to each of the four pigs for the two ten-day periods (eight digestion trials) were as follows: dry substance, 86.2; nitrogen-free extract, 91.5; crude fiber, 38.8; crude protein, 74.0; and ether extract, 64.9. These results for the dry substance, the crude protein, and the nitrogen-free extract agree closely with the corresponding average results obtained in the eight digestion experiments with corn reported in the first series of experiments.

On comparing the average coefficients of the nutrients of the ration of ground corn fed alone with the corresponding averages for the ration of ground barley fed alone, it will be noted that all of the nutrients of the ground corn were digested much more thoroly than those of the ground barley alone.

Ground Barley and Ground Corn (1 to 1).—The coefficients of digestibility of the nutrients of the ration of ground barley and ground

TABLE 13.—COEFFICIENTS OF DIGESTIBILITY

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
First Test Period. November 27 to December 6, 1914. Ten Days. Barley					
114	73.5	81.9	20.9	60.4	64.9
214	71.9	81.1	14.0	57.4	27.2
314	69.8	80.4	15.5	51.6	28.2
414	71.3	82.9	5.9[1]	53.0	24.1
Average	71.6	81.6	16.8	55.6	36.1
Second Test Period. December 7 to 16, 1914. Ten days. Barley					
114	74.2	84.8	10.1	55.5	64.6
214	70.0	80.3	7.5	56.8	22.1
314	67.7	79.1	9.2	48.2	22.8
414	67.6	78.7	18.7	48.8	10.2
Average	69.9	80.7	11.4	52.3	29.9
Third Test Period. January 17 to 26, 1915. Ten days. Barley and ground corn (1 to 1)					
114	82.1	88.9	18.8	70.1	80.6
214	80.8	88.4	10.0	67.1	76.2
314	81.0	89.5	1.4[1]	66.5	66.2
414	81.0	89.6	12.3	63.9	72.7
Average	81.2	89.1	13.7	66.9	73.9
Fourth Test Period. January 27 to February 5, 1915. Ten days. Barley and ground corn (1 to 1)					
114	82.1	89.5	18.2	69.9	65.3
214	80.5	88.2	17.8	65.5	72.1
314	80.0	88.1	20.6	65.5	49.8
414	79.6	88.4	8.5	63.5	59.5
Average	80.6	88.6	16.3	66.1	61.7
Fifth Test Period. March 6 to 15, 1915. Ten days. Ground corn					
114	87.2	91.9	40.1	74.8	78.3
214	86.4	91.2	40.9	74.6	72.3
314	85.7	91.2	38.4	73.0	60.3
414	85.2	91.0	32.6	72.9	58.4
Average	86.1	91.3	38.0	73.8	67.3
Sixth Test Period. March 16 to 25, 1915. Ten days. Ground corn					
114	86.2	91.6	38.2	72.8	64.9
214	87.7	92.0	45.0	77.5	75.6
314	85.4	91.6	40.0	73.2	57.2
414	85.3	91.3	35.0	73.2	52.0
Average	86.2	91.6	39.6	74.2	62.4

[1] Not included in the average.

TABLE 13.—*Concluded*

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
Seventh Test Period. April 22 to May 1, 1915. Ten days. Tankage and ground corn (1 to 7.5)					
114	84.1	91.3	48.6	72.5	73.5
214	87.2	93.1	59.4	76.2	76.2
314	85.2	91.7	50.7	75.4	69.2
414	85.2	91.2	51.1	74.4	79.3
Average	85.4	91.8	52.5	74.6	74.6
Eighth Test Period. May 2 to 11, 1915. Ten days. Tankage and ground corn (1 to 7.5)					
114	86.5	93.5	50.9	74.2	82.0
214	87.1	93.0	60.0	76.1	84.0
314	83.0	89.9	45.7	72.4	70.7
414	83.6	90.4	45.3	73.0	71.2
Average	85.1	91.7	50.5	73.9	77.0

TABLE 14.—SUMMARY OF THE AVERAGE COEFFICIENTS OF DIGESTIBILITY OF THE RATIONS

	Period	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
Ground barley	1	71.6	81.6	16.8	55.6	36.1
Ground barley	2	69.9	80.7	11.4	52.3	29.9
Average		70.8	81.2	14.1	54.0	33.0
Ground barley and ground corn	3	81.2	89.1	13.7	66.9	73.9
Ground barley and ground corn	4	80.6	88.6	16.3	66.1	61.7
Average		80.9	88.9	15.0	66.5	67.8
Ground corn	5	86.1	91.3	38.0	73.8	67.3
Ground corn	6	86.2	91.6	39.6	74.2	62.4
Average		86.2	91.5	38.8	74.0	64.9
Tankage and ground corn	7	85.4	91.8	52.5	74.6	74.6
Tankage and ground corn	8	85.1	91.7	50.5	73.9	77.0
Average		85.3	91.8	51.5	74.3	75.8

corn fed together in the ratio of 1 to 1 in Periods 3 and 4 varied for the different animals during the same period. This is especially true of the coefficients for the crude fiber, the ether extract, and the crude protein. The average coefficients of digestibility of the nutrients of this ration except the ether extract and the crude fiber agreed very closely for the two periods.

The average coefficients of digestibility of the nutrients of the ration of ground barley and ground corn fed together in the ratio of 1 to 1 to each of the four pigs for the two ten-day periods (eight digestion trials) were as follows: dry substance, 80.9; nitrogen-free extract, 88.9; crude fiber, 15.0; crude protein, 66.5; and ether extract, 67.8. On comparing the average coefficients of the nutrients of the ration of ground barley and ground corn fed together in the ratio of 1 to 1 with those of the rations of ground barley and of ground corn when fed alone, it will be noted that the coefficients of the nutrients for the ration of barley and corn were in all cases, excepting those of the ether extract, intermediate between those of the barley fed alone and those of the corn fed alone.

Tankage and Ground Corn (1 to 7.5).—The coefficients of digestibility of the nutrients of this ration varied significantly for the different pigs during the same period. The average coefficients of all the nutrients of this ration agreed closely for the two experimental periods.

The average coefficients of digestibility of the nutrients of the ration of tankage and ground corn fed together in the ratio of 1 to 7.5 to each of the four pigs for the two ten-day periods (eight digestion trials) were as follows: dry substance, 85.3; nitrogen-free extract, 91.8; crude fiber, 51.5; crude protein, 74.3; and ether extract, 75.8. These results agree quite closely with the corresponding average results obtained in the eight digestion experiments with the same ration reported above in the first series of experiments.

On comparing the average coefficients of the nutrients of this ration with those of the ration of ground barley when fed alone, it will be noted that all of the nutrients of the tankage and ground corn were digested much more thoroly than those of the barley.

A comparison of the average coefficients of the nutrients of the ration of tankage and ground corn fed together with the ration of corn fed alone shows that the dry substance, the crude protein, and the nitrogen-free extract of the tankage and corn were digested to practically the same extent as those of the ground corn alone, while the ether extract and the crude fiber of the tankage and corn were digested much more thoroly than those of the ground corn alone. These findings are in accord with those obtained in the first series of experiments.

THE INFLUENCE OF ONE FEED UPON THE DIGESTIBILITY OF THE NUTRIENTS OF ANOTHER FEED

The data for the coefficients of digestibility of the nutrients of barley, as determined directly when fed alone, and as calculated indirectly from the results of direct digestion experiments with the combined ration composed of barley and ground corn and the ground corn alone, are given in Table 15. It will be noted that the individual data and the average data for the four pigs show that the calculated values indirectly determined for the coefficients of digestibility of the dry substance, the nitrogen-free extract, the crude protein, and the ether

TABLE 15.—COEFFICIENTS OF DIGESTIBILITY OF GROUND BARLEY, DIRECTLY AND INDIRECTLY DETERMINED

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
Ground barley fed alone. First Test Period					
114	73.5	81.9	20.9	60.4	64.9
214	71.9	81.1	14.0	57.4	27.2
314	69.8	80.4	15.5	51.6	28.2
414	71.3	82.9	5.9	53.0	24.1
Average	71.6	81.6	16.8	55.6	36.1
Ground barley calculated from the barley and corn ration. Third and Fifth Periods					
114	77.3	86.0	10.0	66.1	84.5
214	75.5	85.6	–2.9	60.8	83.0
314	76.5	87.8	–13.9	61.0	76.4
414	77.9	88.3	3.9	56.3	76.0
Average	76.8	86.9	–0.7	61.1	80.0
Ground barley fed alone. Second Test Period					
114	74.2	84.8	10.1	55.5	64.6
214	70.0	80.3	7.5	56.8	22.1
314	67.7	79.1	9.2	48.2	22.8
414	67.6	78.7	18.7	48.8	10.2
Average	69.9	80.7	11.4	52.3	29.9
Ground barley calculated from corn and barley ration. Fourth and Sixth Test Periods					
114	78.3	87.4	9.9	67.4	66.0
214	73.7	84.4	6.5	55.3	66.1
314	74.9	84.6	12.6	59.1	37.0
414	74.3	85.4	–2.6	55.3	61.8
Average	75.3	85.5	6.6	59.3	57.7

extract of the barley are considerably higher than the corresponding coefficients of the barley determined directly by the digestion experiments.

While the calculated results for the crude fiber are irregular, they nevertheless indicate that the calculated coefficients indirectly determined for this nutrient of the barley are, on the whole, somewhat lower than the corresponding coefficients of the barley determined directly.

The data for the coefficients of digestibility of the nutrients of the ground corn, as determined directly when fed alone, and as calculated indirectly from the direct experiments with the ration composed of barley and ground corn and the barley alone, are given in Table 16. A study of these data leads, in general, to the same conclusions as to the variations and differences between the direct and indirect coefficients of the nutrients of ground corn as were found in the case of the direct and indirect coefficients for barley.

The data for the coefficients of digestibility of the nutrients of the ration composed of one part of ground barley and one part of ground corn, as determined directly and as calculated indirectly, first, from the direct determinations for the barley and the corn rations, and second, from the indirect determinations for the barley and the corn rations are given in Table 17. It is apparent that the coefficients for the dry substance, the nitrogen-free extract, the crude protein, and the ether extract of the ration calculated from the coefficients for the ground barley and the ground corn, each determined directly, are considerably lower, while those for the crude fiber are considerably higher, than the corresponding coefficients directly determined for the mixed ration. These findings seem to prove that the dry substance,

TABLE 16.—COEFFICIENTS OF DIGESTIBILITY OF GROUND CORN, DIRECTLY AND INDIRECTLY DETERMINED

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
Ground corn fed alone. Fifth Test Period					
114	87.2	91.9	40.1	74.8	78.3
214	86.4	91.2	40.9	74.6	72.3
314	85.7	91.2	38.4	73.0	60.3
414	85.2	91.0	32.6	72.9	58.4
Average	86.1	91.3	38.0	73.8	67.3
Ground corn calculated from the barley and corn ration. First and Third Test Periods					
114	91.2	96.0	13.9	81.6	89.5
214	90.2	95.7	0.2	78.7	58.2
314	92.8	98.6	-32.5	84.2	88.0
414	92.2	96.4	30.5	76.9	56.4
Average	91.6	96.7	3.0	80.4	73.0
Ground corn fed alone. Sixth Test Period					
114	86.2	91.6	38.2	72.8	64.9
214	87.7	92.0	45.0	77.5	75.6
314	85.4	91.6	40.0	73.2	57.2
414	85.3	91.3	35.0	73.2	52.0
Average	86.2	91.6	39.6	74.2	62.4
Ground corn calculated from the barley and corn ration. Second and Fourth Test Periods					
114	90.5	94.3	37.7	86.9	65.7
214	91.6	96.1	42.5	75.7	44.7
314	93.0	97.2	48.3	86.1	65.4
414	92.4	98.0	-16.2	80.9	81.6
Average	91.9	96.4	28.1	82.4	64.4

TABLE 17.—COEFFICIENTS OF DIGESTIBILITY OF A RATION OF GROUND BARLEY AND GROUND CORN (1 TO 1), DIRECTLY AND INDIRECTLY DETERMINED

Pig	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
Ground barley and ground corn (1 to 1) fed together, direct determination. Third Test Period					
114	82.1	88.9	18.8	70.1	80.6
214	80.8	88.4	10.0	67.1	76.2
314	81.0	89.5	1.4	66.5	66.2
414	81.0	89.6	12.3	63.9	72.7
Average	81.2	89.1	13.7	66.9	73.9
Ground barley and ground corn (1 to 1) calculated from the direct determinations of the barley ration and the corn ration. First and Fifth Test Periods					
114	80.2	86.9	26.5	67.0	73.4
214	79.0	86.1	21.9	65.3	55.9
314	77.5	85.8	22.2	61.4	48.6
414	78.1	86.9	13.7	62.1	45.9
Average	78.7	86.4	21.1	64.0	56.0
Ground barley and ground corn (1 to 1) calculated from the indirect determinations for the barley ration and the corn ration (see second sections of Tables 15 and 16)					
114	87.1	91.0	11.1	73.2	87.7
214	82.7	90.6	–2.0	69.0	91.0
314	84.4	93.2	–19.3	71.6	83.8
414	84.9	92.3	11.0	65.7	98.7
Average	84.0	91.8	0.2	69.9	90.3
Ground barley and ground corn (1 to 1) fed together, direct determination. Fourth Test Period					
114	82.1	89.5	18.2	69.9	65.3
214	80.5	88.2	17.8	65.5	72.1
314	80.0	88.1	20.6	65.5	49.8
414	79.6	88.4	8.5	63.5	59.5
Average	80.6	88.6	16.3	66.1	61.7
Ground barley and ground corn (1 to 1) calculated from the direct determinations of the barley ration and the corn ration. Second and Sixth Test Periods					
114	80.0	88.2	18.3	63.4	64.8
214	78.6	86.1	18.5	66.3	56.1
314	76.3	85.3	18.2	59.6	44.7
414	76.2	85.0	23.5	60.0	42.1
Average	77.8	86.2	19.6	62.3	51.9
Ground barley and ground corn (1 to 1) calculated from the indirect determination of the barley ration and the corn ration (see fourth sections of Tables 15 and 16)					
114	84.2	90.8	18.0	76.3	65.8
214	82.4	90.2	17.0	64.7	87.1
314	83.8	90.9	23.1	71.4	55.0
414	83.1	91.1	–6.5	67.0	76.6
Average	83.4	90.8	12.9	69.9	71.1

the nitrogen-free extract, the crude protein, and the ether extract of the two feeds when fed together are more digestible than they are when fed alone, while the crude fiber is less digestible. On the other hand, it is evident from the data given in Table 17 that the coefficients for the dry substance, the nitrogen-free extract, the crude protein, and the ether extract of the ration calculated from the coefficients determined indirectly for the barley and the ground corn rations are considerably higher, while those of the crude fiber are considerably lower, than the corresponding coefficients directly determined for the mixed ration.

It should be noted in this connection that the coefficients for the dry substance and the nitrogen-free extract for the wheat flour middlings and the ground corn ration, calculated from the direct determinations of the middlings and the ground corn fed singly (see page 69), were *considerably higher* than those directly determined from the mixed ration. However, the coefficients for the dry substance and the nitrogen-free extract for the barley and ground corn ration, calculated from the direct determinations of the barley and ground corn fed singly (see page 83), were *considerably lower* than those directly determined from the mixed ration. Further, the coefficients for the protein of the wheat flour middlings and the ground corn ration, calculated from the direct determinations of the middlings and the ground corn fed singly, were *not much different* from those directly determined for the mixed ration. However the coefficients for the protein of the barley and ground corn ration, calculated from the direct determinations of the barley and corn fed singly, were *considerably lower* than those directly determined from the mixed ration.

It is therefore evident that, in some cases, one feed does not influence the digestibility of the individual nutrients of another feed and, in other cases, it does influence the digestibility of the individual nutrients of the other feed in one of the two following ways: first, the nutrients of the feeds when fed as mixed feeds are more digestible than they are when each feed is used alone; or, second, the nutrients of feeds when fed as mixed feeds are less digestible than they are when each feed is used alone. With the limited data at present available relating to this subject, it is impossible to explain logically the above mentioned differences shown by different combinations of feeds upon the digestibility of their nutrients as compared with the digestibility of the nutrients of the individual feeds when fed alone. This subject is being further studied at this station.

The results of these researches on the influence of one feed upon the digestibility of another feed demonstrate clearly, first, that the coefficients of digestibility of feeds calculated indirectly by subtracting the weights of the digestible nutrients of one feed as directly determined in other periods from the corresponding values for two feeds combined may be, and probably often are, decidedly inaccurate; and second, that the weights of the digestible nutrients of a mixed ration calculated by the use of the coefficients of digestibility of the nutrients obtained directly for the individual feeds when fed alone may be decidedly inaccurate.

It therefore seems evident from these considerations that, in order to obtain accurate results for the coefficients of digestibility of mixed rations, digestion experiments should be made directly upon the mixed rations as fed. In other words, in the future, coefficients of digestibility of the nutrients for *mixed* rations should be obtained and reported, rather than merely those for the *individual* feeds composing the rations.

INDIVIDUALITY OF PIGS AS TO THE THORONESS WITH WHICH THEY DIGEST THEIR FEED

The data for the coefficients of digestibility of the crude protein obtained in thirty-two digestion trials of ten days each, in which four rations were fed to each of four pigs, are given in Table 18. Examination of the figures shows that the individual coefficients for Pig 214 are significantly greater than the individual coefficients for Pig 414, in each of the eight experiments. A similar comparison of the coefficients of digestibility of protein for Pigs 214 and 314 demonstrates a similar significant difference. Since conditions thruout the experiment were practically identical, the pigs also being litter mates and having been fed together from birth, the data lead clearly to the conclusion that the distinct and well-defined differences between the coefficients of digestibility of crude protein for Pig 214 and Pigs 314 and 414 thruout the eight experiments must have been due to individuality. A further study of the data of this table shows that there is a considerable difference between the coefficients of digestibility of crude protein for Pigs 114 and 314 and for Pigs 114 and 414 that apparently can be assigned to the factor of individuality. However, there are practically no differences in the coefficients of digestibility of crude protein for Pigs 114 and 214, or for Pigs 314 and 414, that can be assigned to the factor of individuality.

Examination of the results presented in Table 18 for the coefficients of digestibility of the ether extract of the four rations shows that there were marked and well-defined differences due apparently to the individuality of the pigs.

Inspection of the data given in Table 18 for the coefficients of the dry matter and the nitrogen-free extract, shows that there was a tendency toward individual differences especially in the average results. However, the individuality of these pigs with reference to their power of digesting dry matter and nitrogen-free extract is not so clearly evident as it is in the case of crude protein and ether extract.

TABLE 18.—SUMMARY OF THE COEFFICIENTS OF DIGESTIBILITY OF THE NUTRIENTS SHOWING THE INDIVIDUALITY OF PIGS AS TO THE THORONESS WITH WHICH THEY DIGESTED THEIR FEED

Period	Ration	Pig 214	Pig 114	Pig 314	Pig 414	Pig 214	Pig 114	Pig 314	Pig 414
		Crude protein				Ether extract			
1	Barley (alone)...	57.4	60.4	51.6	53.0	64.9	27.2	24.1	28.2
2	Barley (alone)...	56.8	55.5	48.2	48.8	64.6	22.1	10.2	22.8
3	Barley and corn (1 to 1).......	67.1	70.1	66.5	63.9	80.6	76.2	72.7	66.2
4	Barley and corn (1 to 1).......	65.5	69.9	65.5	63.5	65.3	72.1	59.5	49.8
5	Ground corn (alone)........	74.6	74.8	73.0	72.9	78.3	72.3	58.4	60.3
6	Ground corn (alone)........	77.5	72.8	73.2	73.2	64.9	75.6	52.0	57.2
7	Tankage and corn (1 to 7.5)......	76.2	72.5	75.4	74.4	73.5	76.2	79.3	69.2
8	Tankage and corn (1 to 7.5)......	76.1	74.2	72.4	73.0	82.0	84.0	71.2	70.7
	Average.....	68.9	68.8	65.7	65.3	71.8	63.2	53.4	53.1
		Dry substance				Nitrogen-free extract			
1	Barley (alone)...	73.5	71.9	71.3	69.8	81.9	81.1	82.9	80.4
2	Barley (alone)...	74.2	70.0	67.6	67.7	84.8	80.3	78.7	79.1
3	Barley and corn (1 to 1).......	82.1	80.8	81.0	81.0	88.9	88.4	89.6	89.5
4	Barley and corn (1 to 1).......	82.1	80.5	79.6	80.0	89.5	88.2	88.4	88.1
5	Ground corn (alone)........	87.2	86.4	85.2	85.7	91.9	91.2	91.0	91.2
6	Ground corn (alone)........	86.2	87.7	85.3	85.4	91.6	92.0	91.3	91.6
7	Tankage and corn (1 to 7.5)......	84.1	87.2	85.2	85.2	91.3	93.1	91.2	91.7
8	Tankage and corn (1 to 7.5)......	86.5	87.1	83.6	83.0	93.5	93.0	90.4	89.9
	Average.....	81.9	81.5	79.9	79.5	89.2	88.4	87.9	87.7

The results of this second series of experiments show greater differences in the coefficients of digestibility of the nutrients of the same feeds by different animals than did those of the first series. For example, the average coefficient of digestibility of the protein in the eight tests for Pig 214 was 5.5 percent greater than that for Pig 414. Again, the average coefficient of digestibility of the ether extract in the eight tests for Pig 114 was 35.2 percent greater than that for Pig 414. The total gain in live weight of Pig 114 for the 80 days was 26.3 percent greater than that for Pig 414.

The results of this second series of experiments support those obtained in the first series of experiments in demonstrating that the coefficients of digestibility of the nutrients of a number of different rations show constantly higher values for some pigs than for others.

The total gains in weight of each of the four pigs used in this experiment during the eight experimental periods, each of ten days' duration during which time each of the four animals received the same kind of feeds and approximately the same quantity of feeds per 100 pounds of live weight, were as follows: Pig 114, 62.5 pounds; Pig 214, 57.0 pounds; Pig 314, 54.5 pounds; and Pig 414, 49.5 pounds. The average live weights of the pigs during the eight experimental periods were as follows: Pig 114, 277.5 pounds; Pig 214, 229.8 pounds; Pig 314, 218.3 pounds; and Pig 414, 200.5 pounds. The weights of the total feeds consumed during this same time were as follows: Pig 114, 459.2 pounds; Pig 214, 376.8 pounds; Pig 314, 364.0 pounds; and Pig 414, 335.6 pounds. The weights of feed required to produce 100 pounds of gain during the ten experimental periods were as follows: Pig 114, 735 pounds; Pig 214, 661 pounds; Pig 314, 668 pounds; and Pig 414, 678 pounds.

Comparing these gains in live weight and the economy of gains in weight with the average coefficients of digestibility of the nutrients of the feeds for each animal, it will be observed that there is possibly a better correlation between the coefficients of digestibility and the gains or the economy of the gains in weight in this second series of experiments than there was in the first series. For example Pig 214, which on the average digested all of the nutrients of the feeds somewhat more thoroly than Pigs 314 and 414, altho weighing on an average 277.5 pounds, made a gain of 57 pounds and required only 661 pounds of feed to produce 100 pounds of gain; while Pigs 314 and 414, weighing only 218.3 and 200.5 pounds, respectively, made gains of 54.5 and 49.5 pounds, respectively, and required 668 and 678 pounds of feed, respectively, to produce 100 pounds of gain. These results would seem to indicate that Pig 214 possibly made more economical gains than Pigs 314 and 414. Further, Pig 314, which on the average digested all of the nutrients of the feeds only very slightly more thoroly than Pig 414, altho weighing somewhat more than that pig, yet possibly made slightly the more economical gains of the two. On the other hand, Pig 114, which on the average digested all of the nutrients of the feeds almost as thoroly as Pig 214, altho weighing 47.7 pounds more than Pig 214, gained 62.5 pounds but required 735 pounds of feed to produce 100 pounds of gain, while Pig 214 gained 57 pounds and required only 661 pounds of feed to produce 100 pounds of gain. However, the difference between these two pigs as to economy of gains may be due, in large part at least, to the difference in their live weights.

SUMMARY OF DATA OF BOTH SERIES OF EXPERIMENTS

1. *Dry Substance.*—The order of the rations according to decreasing coefficients of digestibility of their dry substance was as follows: ground corn, 87.1; tankage and ground corn, 86.0; ground barley and ground corn, 80.9; wheat flour middlings and ground corn, 79.1; wheat flour middlings, 74.4; and ground barley, 70.8.

2. *Nitrogen-free Extract.*—The order of the rations according to decreasing coefficients of digestibility of their nitrogen-free extract was as follows: tankage and ground corn, 92.2; ground corn, 92.1; ground barley and ground corn, 88.9; wheat flour middlings and ground corn, 85.9; wheat flour middlings, 81.2; and ground barley, 81.2.

3. *Crude Fiber.*—The order of the rations according to decreasing coefficients of digestibility of their crude fiber was as follows: tankage and ground corn, 51.2; ground corn, 34.8; wheat flour middlings, 21.0; ground barley and ground corn, 15.0; ground barley, 14.1; and wheat flour middlings and ground corn, 12.1.

4. *Crude Protein.*—The order of the rations according to decreasing coefficients of digestibility of their crude protein was as follows: wheat flour middlings, 80.0; wheat flour middlings and ground corn, 77.3; tankage and ground corn, 74.8; ground corn, 74.5; ground barley and ground corn, 66.5; and ground barley, 54.0.

5. *Ether Extract.*—The order of the rations according to decreasing coefficients of digestibility of the ether extract was as follows: wheat flour middlings, 85.4; wheat flour middlings and ground corn, 83.4; tankage and ground corn, 80.8; ground corn, 68.3; ground barley and ground corn, 67.8; and ground barley, 33.0.

6. *Average Coefficients of Digestibility of the Rations.*—The following is a summary of the average coefficients of the rations fed in these experiments:

Ration	No. of experiments	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
Wheat flour middlings	16	74.4	81.2	21.0	80.0	85.4
Ground corn	16	87.1	92.1	34.8	74.5	68.3
Ground barley	8	70.8	81.2	14.1	54.0	33.0
Wheat flour middlings and ground corn (1 to 1)	8	79.1	85.9	12.1	77.3	83.4
Ground barley and ground corn (1 to 1)	8	80.9	88.9	15.0	66.5	67.8
Tankage and ground corn (1 to 7.5)	16	86.0	92.2	51.2	74.8	80.8

7. *Influence of One Feed upon the Digestibility of the Nutrients of Another Feed.*—The following is a summary of the average results which show the influence of one feed upon the digestibility of another feed:

Ration	No. of experiments	Dry substance	Nitrogen-free extract	Crude fiber	Crude protein	Ether extract
Middlings—direct	8	74.7	82.2	22.8	79.3	82.3
Middlings—indirect	8	70.7	77.2	6.1	78.3	89.3
Corn—direct	8	87.8	92.7	30.8	75.1	71.7
Corn—indirect	8	83.7	88.9	-2.2	73.0	81.3
Barley—direct	8	70.8	81.2	14.1	54.0	33.0
Barley—indirect	8	76.1	86.2	3.7	60.2	68.9
Corn—direct	8	86.2	91.5	38.8	74.0	64.9
Corn—indirect	8	91.8	96.6	15.6	81.4	68.7
Middlings and corn—direct	8	79.1	86.0	12.1	77.3	83.5
Middlings and corn—indirect[1]	8	81.1	88.1	24.8	78.0	78.8
Middlings and corn—indirect[2]	8	77.1	83.8	-0.7	76.6	88.1
Barley and corn—direct	8	80.9	88.9	15.0	66.5	67.8
Barley and corn—indirect[1]	8	78.3	86.3	20.4	63.2	54.0
Barley and corn—indirect[2]	8	83.7	91.3	6.6	69.9	80.7

[1] Calculated from the direct determinations of the coefficients of the individual feeds.

[2] Calculated from the indirect determinations of the coefficients of the individual feeds.

8. *Individuality of Pigs as to the Thoroness With Which They Digest Their Feeds.*—Summaries of the nutrients of the feeds showing the individuality of pigs as to the thoroness with which they digest their feeds are given on pages 72 and 87 of this bulletin.

CONCLUSIONS

1. The weights of the feces of pigs, per pound of feed, vary markedly depending upon the character of the ration. Such differences in the weights of the feces per pound of feed are due, in large part at least, to variations in the water content of the feces and to variations in the coefficients of digestibility of the dry substance of the rations.

2. The results obtained in these experiments clearly indicate that in some cases one feed does not influence the digestibility of the individual nutrients of another feed with which it is fed, and in other cases that it does influence the digestibility of the individual nutrients of the other feed in one of the two following ways: first, the nutrients of the feeds when fed as mixed feeds are more digestible than they are when each feed is used alone; or, second, the nutrients of the feeds when fed as mixed feeds are less digestible than they are when each feed is used alone. With the limited data at present available relating

to this subject, it is impossible to explain logically these differences shown by different combinations of feeds, when fed together, upon the digestibility of their combined nutrients as compared with the digestibility of the nutrients of the individual feeds when fed alone.

3. The results of these researches on the influence of one feed upon the digestibility of another feed demonstrate clearly: first, that the coefficients of digestibility of the nutrients of feeds calculated indirectly by subtracting the weights of the digestible nutrients of one feed as directly determined in other tests from the corresponding values for the two feeds combined, may be, and probably often are, decidedly inaccurate; and second, that the weights of the digestible nutrients of a mixed ration, calculated by the use of the coefficients of digestibility of the nutrients obtained directly for the individual feeds when fed alone, may be decidedly inaccurate.

4. It therefore apparently follows that in order to obtain strictly accurate results for the coefficients of digestibility of mixed rations, digestion experiments should be made directly upon the mixed rations as fed. In other words, in the future coefficients of apparent digestibility of the nutrients for *mixed* rations should be obtained and reported, rather than those for *individual* feeds composing the rations.

5. The results of these experiments demonstrate clearly that different animals of the same species may show individuality as to the thoroness with which they digest the nutrients of their feeds. In other words, under conditions that are practically identical thruout the same experiment, the coefficients of digestibility of the nutrients of a number of different rations show significantly higher values for some pigs than for others. However, the differences in the coefficients of digestibility of the nutrients of the same feeds by the different pigs are probably too small to be considered of much, if any, practical or economic importance.

The authors wish to acknowledge the efficient assistance rendered by W. F. Campbell in the feeding, weighing, and care of the animals.

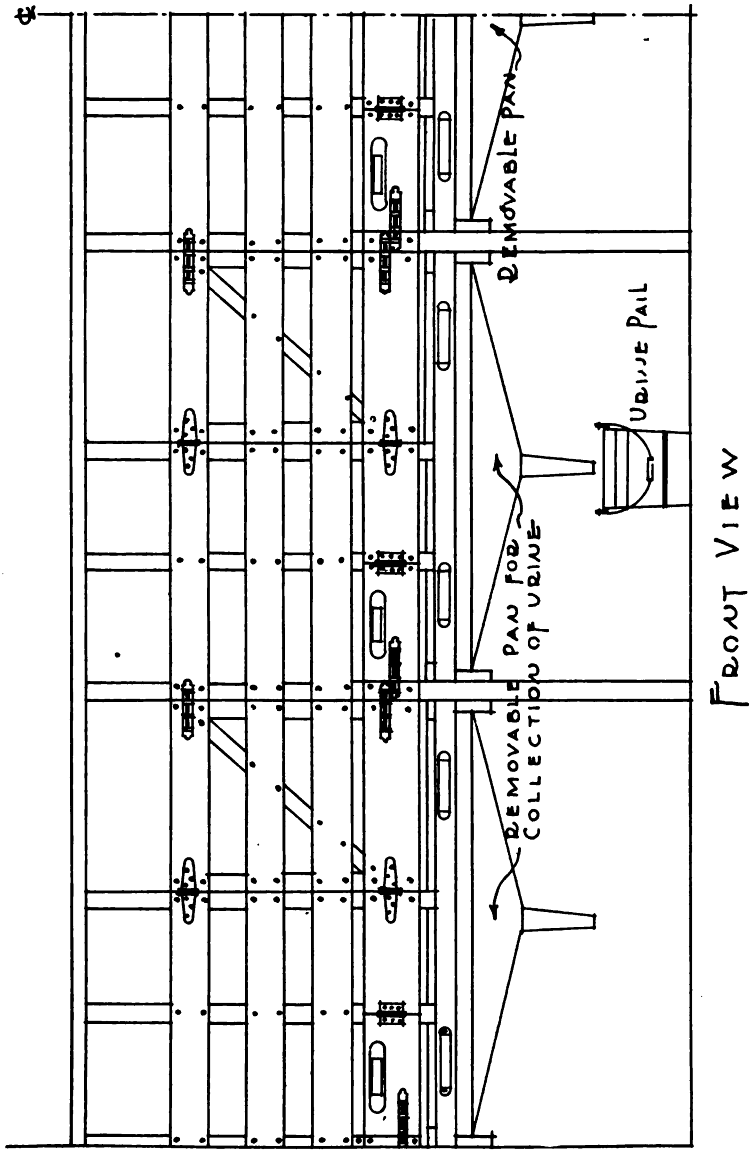
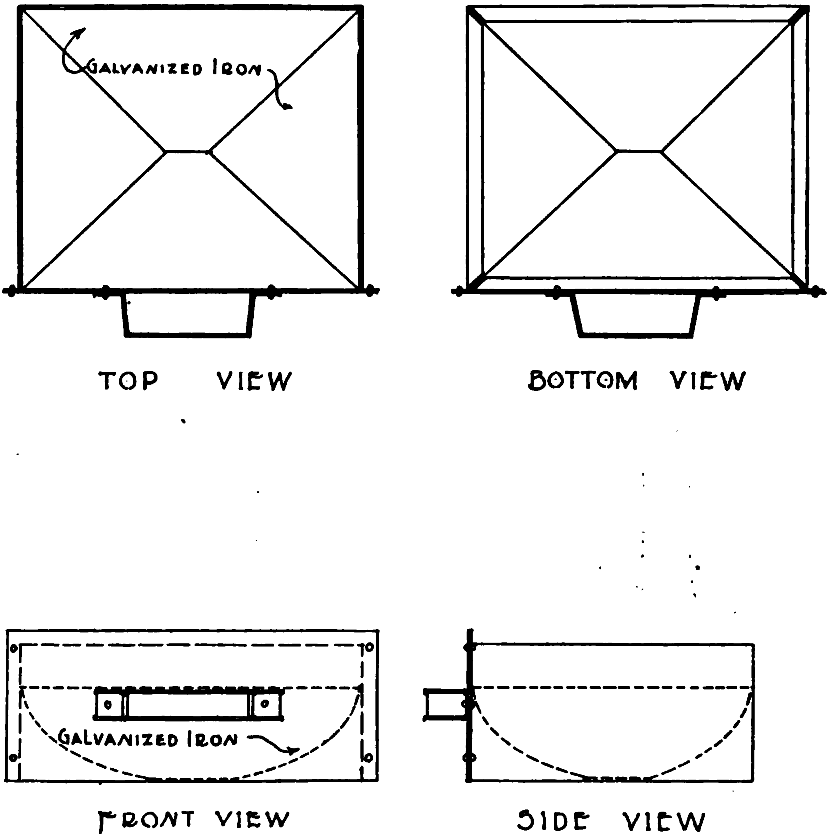


FIG. 1—DIGESTION STALLS FOR SWINE



TOP VIEW BOTTOM VIEW

FRONT VIEW SIDE VIEW

NOTE:-
THE DOTTED LINES SHOW THE CURVATURE OF THE FALSE BOTTOM.

FIG. 2—FEED TROUGH

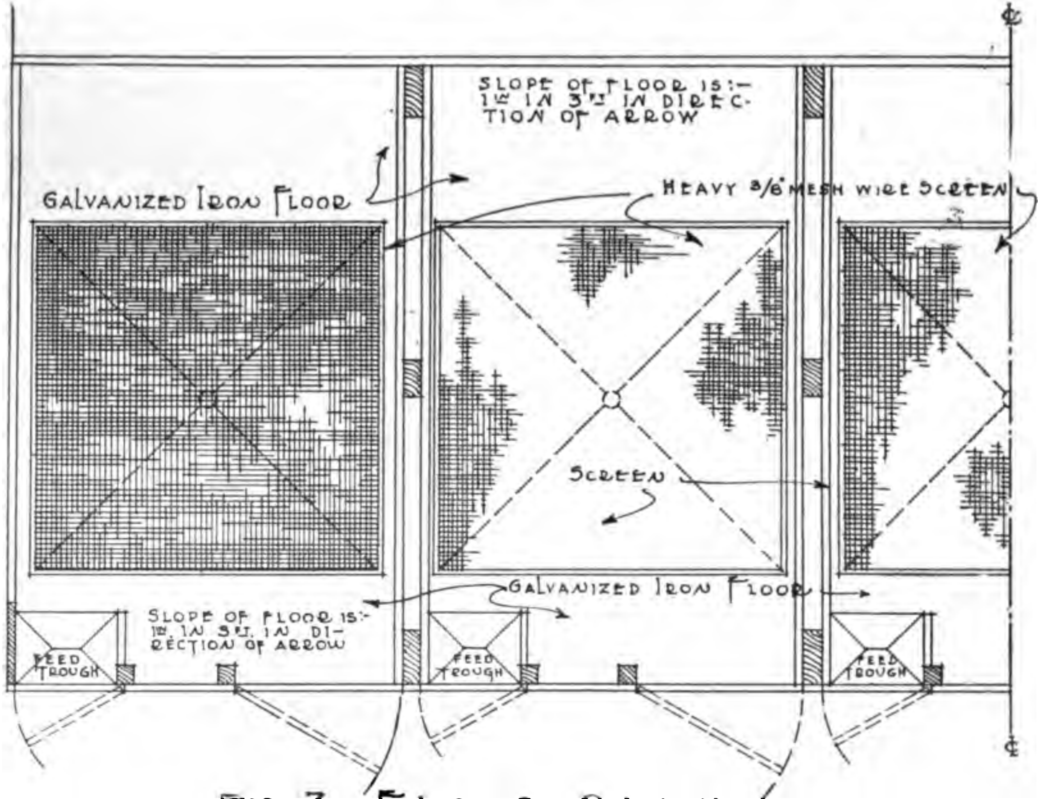

SLOPE OF FLOOR IS:— 1 IN IN 3 FT IN DIRECTION OF ARROW
GALVANIZED IRON FLOOR
HEAVY 3/8" MESH WIRE SCREEN
SCREEN
GALVANIZED IRON FLOOR
SLOPE OF FLOOR IS:— 1 IN IN 3 FT IN DIRECTION OF ARROW
FEED TROUGH
FEED TROUGH
FEED TROUGH

FIG. 3—FLOOR PLAN

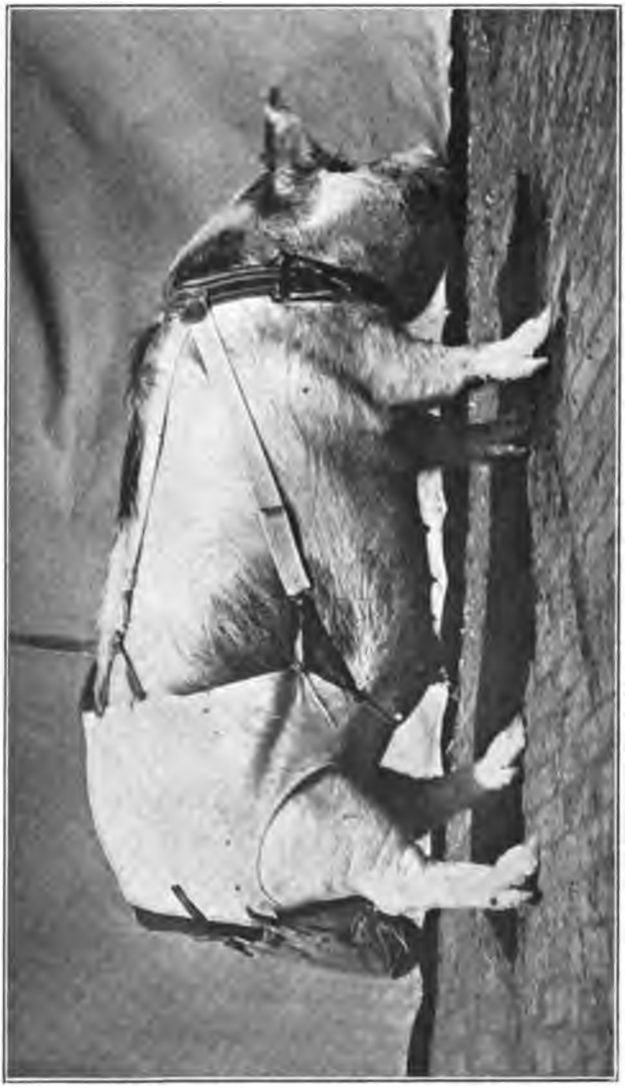


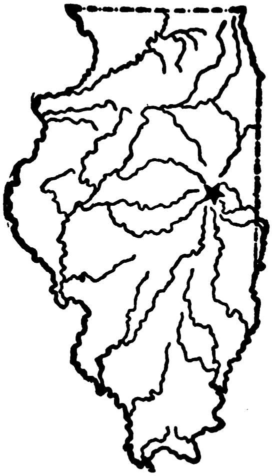
FIG. 4.—DIGESTION HARNESS

UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

BULLETIN No. 201

YIELDS OF WINTER GRAINS IN ILLINOIS

By W. L. BURLISON and O. M. ALLYN



URBANA, ILLINOIS, JUNE, 1917

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SUMMARY OF BULLETIN NO. 201

NORTHERN ILLINOIS.—Continued tests have shown that Turkey Red is the highest-yielding variety of wheat for northern Illinois. The other high-yielding varieties which have been grown for a minimum of three years are Turkey 9–233, Malakoff 5–458, Minnesota Reliable. Kharkof, Wheedling 5–464, and Malakoff. Pages 97–99

Winter rye has yielded more than winter wheat in northern Illinois. Winter barley has not withstood winter-killing. Pages 99, 101

CENTRAL ILLINOIS.—Thirteen varieties of wheat have been grown for five or more years at Urbana. The leading varieties are Turkey Red, Malakoff, Fultz, Hungarian, Pesterboden, Beloglina, Kharkof, and Dawson's Golden Chaff. Other promising varieties are Turkey Hybrid 509 and Dawson's Golden Chaff 9–225. Pages 101–104

SOUTHERN ILLINOIS.—Of the varieties of wheat which have been tested for a minimum of three years, Fulcaster has been the highest-yielding variety. Varieties yielding next in order and which have been tested for a minimum of three years are Economy, Wheedling, Indiana Swamp, Harvest King, Missouri Pride, Rudy, and Poole. Fulcaster was outyielded several years by Economy, Wheedling, Missouri Pride, and Harvest King. The hard wheats are not adapted to conditions in southern Illinois. Pages 104–108

One-year tests with rye, barley, and emmer as winter crops show promising results, but winter oats failed. Pages 106–108

CHARACTERISTICS OF VARIETIES OF WINTER WHEAT. Pages 109–110

YIELDS OF WINTER GRAINS IN ILLINOIS

By W. L. BURLISON, Associate Chief in Crop Production, and
O. M. ALLYN, First Assistant in Crop Production

Winter wheat ranks third among the most important grain crops grown in Illinois. There are numerous varieties of wheat raised in the state, some of which are unsatisfactory, while others are superior strains.

Changing seed wheat is not advisable unless the performance records of the new varieties are thoroly demonstrated in the region in which they are to be used. During late years many varieties of wheat of unknown value have been widely advertised. Notable among these are Alaska, Marvelous, and Miracle. Yields obtained by this station and reports by other investigators prove that misstatements have been printed in advertisements regarding these wheats.

Illinois possesses marked climatic and soil differences, and varieties of wheat suited to one locality are not necessarily the most desirable for another part of the state. The Illinois Experiment Station has conducted experiments with winter grains, not only at Urbana in the central part of the state, but also on crop experiment fields at DeKalb, in northern Illinois, and at Fairfield, in southern Illinois.

The soil on which the experiments at DeKalb and Urbana have been conducted is, for the most part, brown silt loam; at Fairfield, gray silt loam on tight clay. These are the common prairie soils in these regions. The experiment fields have been regularly supplied with phosphate rock and either farm manure or crop residues. Limestone has also been applied at Fairfield and to some extent at Urbana. The aim has been to keep the land in a good state of fertility but not to produce abnormal conditions. It is believed that these fields are such as any progressive Illinois farmer would maintain. Methods of culture which have been followed are comparable to those practiced by leading grain growers of this state. Thus the yields reported are no larger than may well be expected from the respective sections of Illinois. The wheat yields are calculated on the basis of 60 pounds per bushel; rye, 56; barley, 48; and emmer, 30.

NORTHERN ILLINOIS

Tests at DeKalb, in DeKalb County

Wheat.—Variety tests of wheat at the DeKalb experiment field were begun in 1907, and have been conducted in a rotation of corn, oats, wheat, and clover.

Since the varieties have not all been grown for the same number of years, the highest average yield of a variety does not always indicate the best variety, and in order to establish more definitely the relation of the different varieties with respect to yield, all are compared on the same basis, with Dawson's Golden Chaff as a standard. This at once gives a definite rating of the different varieties when compared with a standard variety.

A summary of the varieties tested at DeKalb from 1907 to 1916 appears in Tables 1 and 2. In 1909 and 1912 the winter wheat was a failure as a result of winter-killing.

TABLE 1.—AVERAGE YIELDS OF VARIETIES OF WINTER WHEAT GROWN AT DEKALB, AND PERCENTAGE RATING USING DAWSON'S GOLDEN CHAFF AS A STANDARD

(Bushels per acre)

Variety	1907	1908	1910	1911	1913	1914	1915	1916	Percentage rating
Dawson's Golden Chaff	17.6	40.8	27.0	29.1	34.7	35.5	38.3	23.7	100.0
Turkey Red	24.3	...	37.4	33.9	36.7	39.2	41.6	34.9	120.4
Indiana Swamp	20.3	39.3	27.7	26.0	33.2	29.7	...	...	95.4
Wheedling	17.8	38.1	25.4	25.6	30.1	31.3	...	...	91.1
Kharkof	29.5	...	...	...	32.6	34.0	33.5	33.2	108.7
Minnesota Reliable	...	...	35.7	31.4	33.6	39.6	40.1	...	109.6
Malakoff	22.1	37.8	...	...	34.2	...	...	...	101.1
Turkey 9-233	...	...	...	...	...	35.8	40.8	34.9	114.4
Malakoff 5-458	...	...	...	...	...	34.3	41.5	34.4	113.0
Wheedling 5-464	...	...	...	...	...	38.0	35.9	31.6	108.2
Padi	18.6	26.2	...	...	...	...	...	...	76.7
Native Wheat	...	27.6	29.5	...	...	...	...	...	84.2
Red Hussar	...	...	...	...	34.2	32.5	...	...	95.0
Hungarian	...	...	...	...	34.3	30.1	...	...	91.7
World's Champion	...	...	...	...	...	...	39.8	34.7	120.2
Red Cross	...	...	...	...	...	...	38.8	34.7	118.5
Wisconsin 18	...	...	...	...	...	...	38.0	25.2	101.9
Gypsy	...	...	...	...	...	...	27.9	24.7	84.8
Mediterranean	...	...	...	...	...	...	25.0	25.2	81.0
Miracle	...	...	...	...	...	...	27.9	9.2	59.8
K. B. 2	21.8	...	...	...	...	...	...	...	....
Turkey Red (native)	...	...	...	30.1	...	...	...	...	....
Pesterboden	...	...	...	...	31.1	...	...	...	....
Beloglina	...	...	...	...	29.4	...	...	...	....
Fultz	...	...	...	...	...	30.6	...	...	....
Gold Coin	...	...	...	...	...	32.5	...	...	....
Dawson's Golden Chaff 9-211	...	...	...	...	...	22.6	...	...	....
Salzer's Hardy Northern	...	...	...	...	...	...	...	40.1	....
Red Russian	...	...	...	...	...	...	...	38.6	....
Canadian Hybrid	...	...	...	...	...	...	...	36.8	....
Turkey Hybrid 509	...	...	...	...	...	...	...	36.2	....
Early Red Clawson	...	...	...	...	...	...	...	29.9	....
Rudy	...	...	...	...	...	...	...	26.5	....
Prize Taker	...	...	...	...	...	...	...	23.3	....
Marvelous	...	...	...	...	...	...	...	15.3	....

On an equal basis of comparison with respect to the years tested, Turkey Red has never been out-yielded at DeKalb, as may be seen by looking over Tables 1 and 2. The principal high-yielding varieties which have been grown for a minimum of three years are Turkey Red, Turkey 9-233, Malakoff 5-458, Minnesota Reliable, Kharkof, Wheedling 5-464, and Malakoff. Of the varieties tested for only two years, Red Cross and World's Champion have given good results. Salzer's Hardy Northern, Red Russian, Canadian Hybrid, and Turkey Hybrid 509 have all yielded well for one year, but further tests may prove that they are not so valuable. Considering all the tests up to the present time, Turkey Red and Turkey 9-233 may be regarded as the best-yielding varieties for northern Illinois.

Rye and Barley.—Tests with winter rye and winter barley were begun in 1915. The barley all winter-killed, but the rye made large

TABLE 2.—COMPARABLE AVERAGE YIELDS OF VARIETIES OF WINTER WHEAT GROWN AT DEKALB USING DAWSON'S GOLDEN CHAFF AS A STANDARD
(Bushels per acre)

Variety	Total No. of tests	No. of years compared	Years on which comparison is based	Average yield
Dawson's Golden Chaff.	15	7	1907, 1910, 1911, 1913-1916	29.4
Turkey Red...........	29	7	” ” ” ” ”	35.4
Dawson's Golden Chaff.	11	6	1907, 1908, 1910, 1911, 1913, 1914	30.8
Indiana Swamp........	14	6	” ” ” ” ” ”	29.4
Wheedling............	11	6	” ” ” ” ” ”	28.1
Dawson's Golden Chaff.	13	5	1907, 1913-1916	30.0
Kharkof..............	13	5	” ” ”	32.6
Dawson's Golden Chaff.	12	5	1910, 1911, 1913, 1915, 1916	32.9
Minnesota Reliable.....	12	5	” ” ” ” ”	36.1
Dawson's Golden Chaff.	5	3	1907, 1908, 1913	31.0
Malakoff..............	7	3	” ” ”	31.4
Dawson's Golden Chaff.	8	3	1914-1916	32.5
Turkey 9-233..........	8	3	” ”	37.2
Malakoff 5-458........	8	3	” ”	36.7
Wheedling 5-464........	8	3	” ”	35.2
Dawson's Golden Chaff.	3	2	1907, 1908	29.2
Padi.................	3	2	” ”	22.4
Dawson's Golden Chaff.	4	2	1908, 1910	33.9
Native Wheat.........	4	2	” ”	28.6
Dawson's Golden Chaff.	4	2	1913, 1914	35.1
Red Hussar...........	4	2	” ”	33.3
Hungarian............	4	2	” ”	32.2
Dawson's Golden Chaff.	6	2	1915, 1916	31.0
World's Champion.....	6	2	” ”	37.3
Red Cross............	6	2	” ”	36.8
Wisconsin 18.........	6	2	” ”	31.6
Gypsy................	6	2	” ”	26.3
Mediterranean.........	6	2	” ”	25.1
Miracle..............	6	2	” ”	18.6

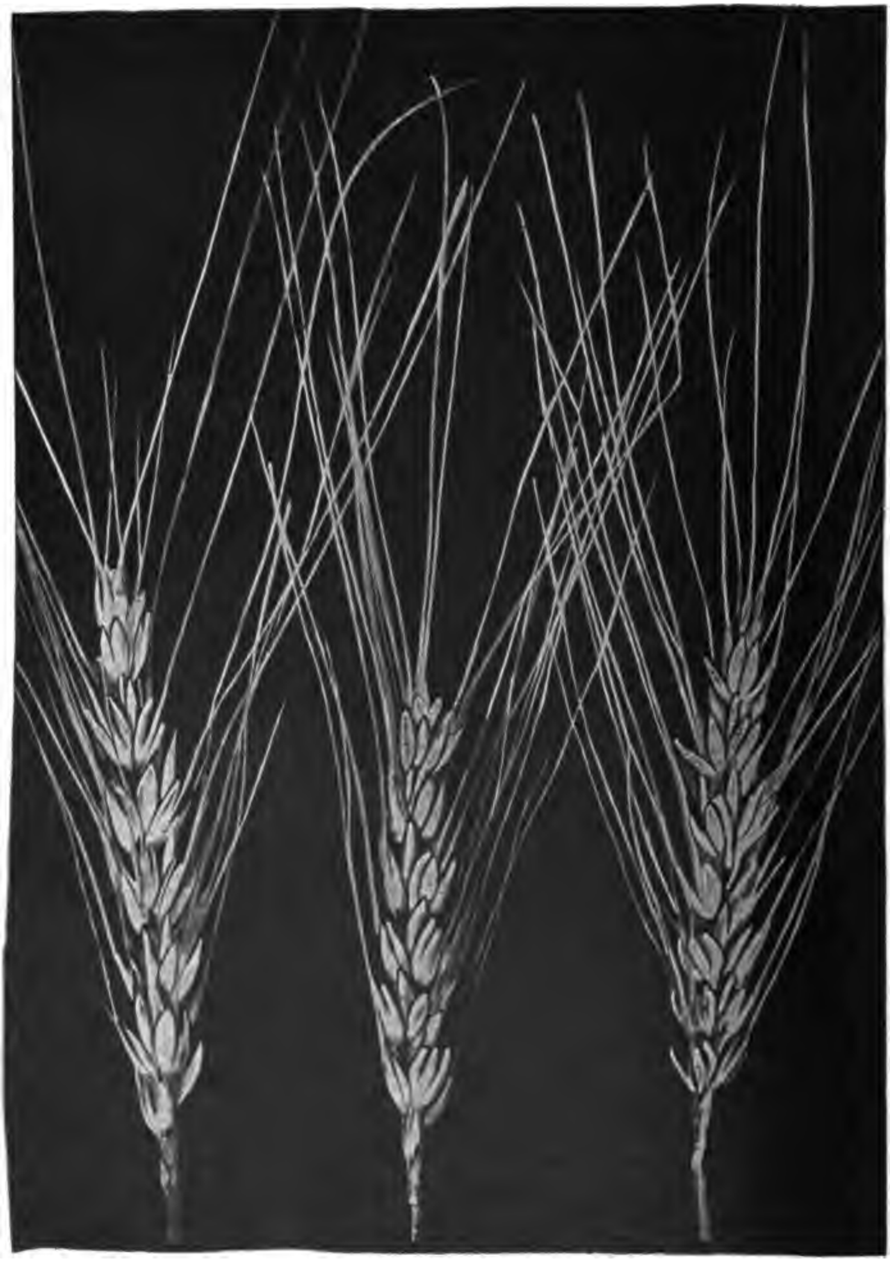

FIG. 1.—TYPICAL HEADS OF TURKEY RED
This type of wheat gave the highest average yield among the varieties tested at Urbana for three or more years

yields. The average yields in bushels per acre of four tests of each variety were as follows:

Petkus winter rye	**55.5**
Wisconsin Pedigree rye	47.0
Michigan winter barley	0.0

CENTRAL ILLINOIS

TESTS AT URBANA, IN CHAMPAIGN COUNTY

Wheat.—The variety trials of wheat on the Urbana field were begun in 1904. The results reported have been obtained from a rotation of wheat, corn, oats, and clover.

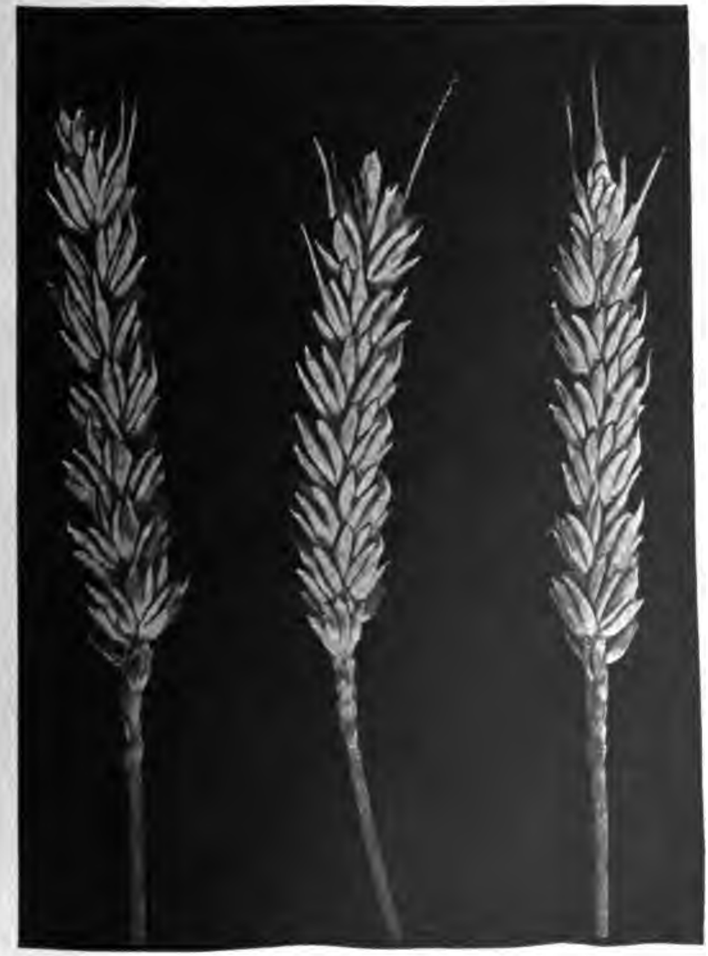

FIG. 2.—DAWSON'S GOLDEN CHAFF
A desirable smooth wheat for central Illinois

TABLE 3.—AVERAGE YIELDS OF VARIETIES OF WINTER WHEAT GROWN AT URBANA, AND PERCENTAGE RATING USING TURKEY RED AS A STANDARD (Bushels per acre)

Variety	1904	1905	1906	1907	1908	1909	1910	1911	1913	1914	1915	1916	Percentage rating
Turkey Red	32.2	30.0	46.6	49.0	43.8	41.4	42.2	51.1	40.9	39.4	49.6	43.0	100.0
Hungarian	18.9	29.0	36.0	43.5	46.0	36.0	38.8	48.6	50.8	34.7	52.8	40.9	93.5
Indiana Swamp	12.8	28.7	37.0	45.2	43.2	28.2	32.7	50.4	59.0	36.0	48.1	33.5	89.3
Dawson's Golden Chaff	16.5	25.1	36.4	46.8	39.1	36.8	...	50.8	56.0	37.2	52.6	37.2	93.1
Beloglina	...	30.8	37.0	39.5	41.4	37.7	44.3	48.4	38.0	43.4	43.8	40.4	93.2
K. B.. 2	...	22.3	40.5	39.2	36.0	40.3	34.0	44.2	42.3	43.5	44.2	32.5	87.8
Red Hussar	...	24.0	40.7	43.7	37.4	40.5	31.8	47.7	36.1	36.9	51.0	26.3	87.2
Wheedling	15.2	25.5	40.2	39.0	41.7	35.5	28.8	52.0	52.0	26.6	...	...	85.6
Pesterboden	...	...	41.1	43.3	44.2	39.0	31.8	48.8	42.8	44.1	47.6	35.3	93.5
Malakoff	31.4	27.7	46.4	45.0	...	...	...	47.3	43.3	44.0	44.4	48.4	99.0
Rudy	12.7	27.9	38.2	44.3	45.3	40.5	17.3	...	...	...	...	26.2	76.9
Kharkof (U. S. 11603)	...	...	39.1	43.5	43.0	37.8	43.0	49.0	...	...	...	...	93.2
Fultz	...	...	...	...	43.7	40.8	26.2	48.5	51.3	...	...	...	95.9
Gold Coin	...	...	...	...	...	...	35.3	43.0	43.2	33.1	...	...	89.0
Red Cross	...	...	...	...	...	...	...	...	...	45.4	42.0	41.2	97.4
Padi	...	...	35.2	32.2	29.0	...	...	...	...	...	...	...	69.2
Satisfaction	13.8	24.3	...	...	...	...	...	...	...	...	...	...	61.3
Jones Longberry	10.4	26.6	...	...	...	...	...	...	...	...	...	...	59.5
Economy	...	...	...	...	...	45.2	33.8	...	...	...	...	...	94.5
Turkey Hybrid 509	...	...	...	...	...	...	...	...	...	...	57.5	48.9	114.9
Dawson's Golden Chaff 9-225	...	...	...	...	...	...	...	...	...	...	54.7	41.2	103.6
Turkey Hybrid 402	...	...	...	...	...	...	...	...	...	...	52.5	33.1	92.4
European	11.9	...	...	...	...	...	...	...	...	...	...	...	37.0
Poole	7.8	...	...	...	...	...	...	...	...	...	...	...	24.2
Minnesota Reliable	...	...	...	...	...	...	...	...	...	...	...	44.0	102.3
Wisconsin 18	...	...	...	...	...	...	...	...	...	...	...	43.8	101.9
World's Champion	...	...	...	...	...	...	...	...	...	...	...	38.6	89.8
Red Wave	...	...	...	...	...	...	...	...	...	...	...	38.2	88.8
Gypsy	...	...	...	...	...	...	...	...	...	...	...	34.5	80.2
Mediterranean	...	...	...	...	...	...	...	...	...	...	...	28.8	67.0
Marvelous	...	...	...	...	...	...	...	...	...	...	...	22.8	53.0
Miracle	...	...	...	...	...	...	...	...	...	...	...	15.0	34.9

TABLE 4.—COMPARABLE AVERAGE YIELDS OF VARIETIES OF WINTER WHEAT GROWN AT URBANA USING TURKEY RED AS A STANDARD

(Bushels per acre)

Varieties	Total number of tests	Number of years compared	Years on which comparison is based	Average yields
Turkey Red	63	12	1904-1911, 1913-1916	42.4
Hungarian	27	12	” ” ” ”	39.7
Indiana Swamp	32	12	” ” ” ”	37.9
Turkey Red	55	11	1904-1909, 1911, 1913-1916	42.5
Dawson's Golden Chaff	28	11	” ” ” ” ”	39.5
Turkey Red	62	11	1905-1911, 1913-1916	43.4
Beloglina	25	11	” ” ” ”	40.4
K. B. 2	26	11	” ” ” ”	38.1
Red Hussar	25	11	” ” ” ”	37.8
Turkey Red	51	10	1904-1911, 1913, 1914	41.7
Wheedling	14	10	” ” ” ”	35.6
Turkey Red	58	10	1906-1911, 1913-1916	44.7
Pesterboden	24	10	” ” ” ”	41.8
Turkey Red	47	9	1904-1907, 1911, 1913-1916	42.4
Malakoff	26	9	” ” ” ” ”	42.0
Turkey Red	31	8	1904-1910, 1916	41.0
Rudy	15	8	” ” ”	31.5
Turkey Red	26	6	1906-1911	45.7
Kharkof (U. S. 11603)	8	6	” ”	42.6
Turkey Red	32	5	1908-1911, 1913	43.9
Fultz	8	5	” ” ”	42.1
Turkey Red	32	4	1910, 1911, 1913, 1914	43.4
Gold Coin	8	4	” ” ” ”	38.6
Turkey Red	24	3	1914-1916	44.0
Red Cross	14	3	” ”	42.9
Turkey Red	6	3	1906-1908	46.5
Padi	3	3	” ”	32.1
Turkey Red	5	2	1904, 1905	31.1
Satisfaction	2	2	” ”	19.0
Jones Longberry	2	2	” ”	18.5
Turkey Red	12	2	1909, 1910	41.8
Economy	3	2	” ”	39.5
Turkey Red	16	2	1915, 1916	46.3
Turkey Hybrid 509	12	2	” ”	53.2
Dawson's Golden Chaff 9-225	12	2	” ”	47.9
Turkey Hybrid 402	12	2	” ”	42.8
Turkey Red	1	1	1904	32.2
European	1	1	”	11.9
Poole	1	1	”	7.8
Turkey Red	8	1	1916	43.0
Minnesota Reliable	8	1	”	44.0
Wisconsin 18	8	1	”	43.8
World's Champion	8	1	”	38.6
Red Wave	8	1	”	38.2
Gypsy	8	1	”	34.5
Mediterranean	8	1	”	28.8
Marvelous	8	1	”	22.8
Miracle	8	1	”	15.0

The complete data are shown in Table 3, and a summary is given in Table 4. There are no data for 1912, as the wheat was winter-killed that year. All varieties are compared with Turkey Red, which has been in the trials from the beginning of these studies. This method of tabulation renders it possible to make a direct comparison of any given group of tests.

Turkey Red, Malakoff, Fultz, Hungarian, Pesterboden, Beloglina, Kharkof, and Dawson's Golden Chaff are the leading varieties of wheat for central Illinois. These varieties have been in the trials for five or more years. There are other promising strains which have been under investigation for a shorter period. Turkey Hybrid 509, developed by the division of plant breeding of the Illinois Experiment Station under the direction of Dr. L. H. Smith, is notable among these. Attention is called to Dawson's Golden Chaff 9-225, which was also developed by Dr. Smith. Red Cross is another promising variety.

SOUTHERN ILLINOIS

TESTS AT FAIRFIELD, IN WAYNE COUNTY

Wheat.—Tests with winter wheat were begun on the Fairfield experiment field in southern Illinois in 1906.

A summary of the results of the tests at Fairfield from 1906 to 1916 appears in Tables 5 and 6. There are no data for 1909, when the wheat was winter-killed. The low yields in 1906 are attributed to the low fertility of the soil, and those in 1915 to a severe hail storm which occurred on June 20.

On a percentage basis, using Fulcaster as the standard for comparison, the following in the order named, have given the highest yields for a minimum of three years: Fulcaster, Economy, Wheedling, Indiana Swamp, Harvest King, Missouri Pride, Rudy, and Poole. It should be noted, however, that if the extremely variable results of 1916 be discarded, then Economy, Wheedling, and Missouri Pride all rank above Fulcaster, while Harvest King takes nearly equal rank.

It will be observed by looking over Table 5 that the hard wheats, such as Turkey Red, Kharkof, and some other varieties which yield the best in central and northern Illinois, do not yield as well as the softer varieties in southern Illinois. Not only are they lower in yield than the softer varieties, but their quality is very inferior. The kernels are nearly always shrivelled or chaffy, and the poor condition of the plants themselves makes it evident that the hard wheats are not adapted to southern Illinois.

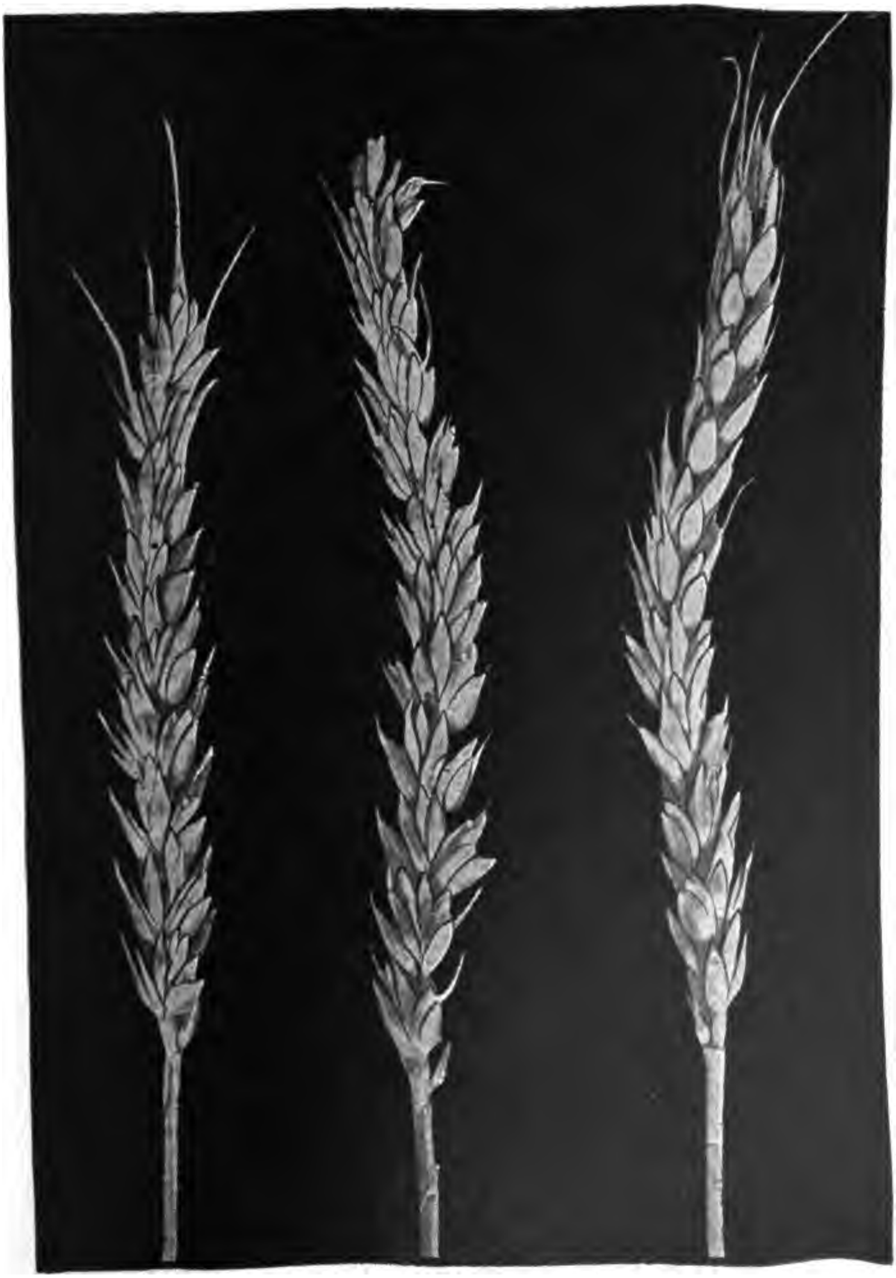

FIG. 3.—HARVEST KING
A leading variety for southern Illinois

TABLE 5.—AVERAGE YIELDS OF VARIETIES OF WINTER WHEAT GROWN AT FAIRFIELD, AND PERCENTAGE RATING USING FULCASTER AS A STANDARD
(Bushels per acre)

Variety	1906	1907	1908	1910	1911	1912	1913	1914	1915	1916	Per-cent-age rating
Fulcaster	3.0	16.3	16.2	33.3	15.7	12.4	17.0	17.0	6.3	22.1	100.0
Wheedling	6.9	16.1	12.1	30.3	21.6	13.3	21.8	20.7	2.5	0.0	91.2
Harvest King	3.5	16.8	13.8	33.9	17.7	13.0	18.4	16.0	3.2	6.2	89.9
Dawson's Golden Chaff	3.4	13.2	17.0	22.4	11.0	14.1	16.5	15.7	...	...	86.6
Indiana Swamp	2.2	14.5	...	25.8	17.1	14.8	15.4	14.4	...	...	90.9
Economy	..	...	...	35.1	18.2	13.6	19.7	19.6	3.9	8.0	95.5
Missouri Pride	..	...	...	34.7	20.6	10.5	22.1	20.1	2.8	0.0	89.3
Red Hussar	2.6	11.4	...	...	...	19.0	10.7	9.8	...	...	81.7
Fultz	..	...	11.5	...	...	11.3	16.5	...	...	...	86.2
Rudy	2.9	16.5	...	...	...	...	...	...	...	17.5	89.1
Poole	6.2	16.0	...	...	...	...	...	...	...	13.8	87.0
Malakoff	2.2	8.5	13.0	...	...	...	...	...	...	...	66.9
Theiss (U.S. 12004)	1.2	6.6	6.3	...	...	...	...	...	...	...	39.8
Hungarian	..	...	...	...	...	15.7	12.4	10.4	...	...	82.6
Kharkof	..	...	...	...	...	11.2	7.5	8.6	...	...	58.7
Jersey Fultz	..	...	...	...	...	...	...	18.6	4.2	9.5	71.5
K. B. 2	4.6	10.2	...	...	...	...	...	...	...	...	76.3
Turkey Red	1.5	11.0	...	...	...	...	...	...	...	...	64.9
Pesterboden	..	...	...	...	...	11.5	10.6	...	...	...	75.5
Beloglina	..	...	...	...	...	8.4	8.5	...	...	...	57.8
Nigger	..	...	...	...	...	...	...	18.0	5.5	...	100.0
Gypsy	..	...	...	...	...	...	...	...	5.4	20.2	90.1
Red Cross	..	...	...	...	...	...	...	...	3.9	11.2	53.5
Mediterranean	..	...	...	...	...	...	...	...	5.9	0.0	21.1
Miracle	..	...	...	...	...	...	...	...	5.2	0.0	18.3
Miller's Pride	7.2	...	...	...	...	...	...	...	...	...	...
Red Wave	..	...	...	...	...	...	...	...	2.0	...	...
Harvest Queen	..	...	...	...	...	...	...	...	...	19.7	...
Early Red Clawson	..	...	...	...	...	...	...	...	...	12.5	...
Marvelous	..	...	...	...	...	...	...	...	...	11.8	...
Turkey Hybrid 509	..	...	...	...	...	...	...	...	...	11.2	...
Worley's Smooth	..	...	...	...	...	...	...	...	...	0.0	...
St. Louis Prize Winner	..	...	...	...	...	...	...	...	1.3	...	...

TESTS AT CUTLER, IN PERRY COUNTY

Wheat.—The earliest variety tests of wheat were started at Cutler, in Perry County, in 1902. In 1907, one year after the regular crop field was started at Fairfield, the Cutler trials were discontinued. The first report of the Cutler variety trials was published in Bulletin 121 of this station. The results are summarized in Tables 7 and 8.

Rye, Barley, Emmer, and Oats.—In the fall of 1915 tests were begun with rye, barley, emmer, and oats, all as winter crops. While these tests have been conducted for only one year, the results are of much interest. Winter rye withstood winter-killing better than

TABLE 6.—COMPARABLE AVERAGE YIELDS OF VARIETIES OF WINTER WHEAT GROWN AT FAIRFIELD USING FULCASTER AS A STANDARD (Bushels per acre)

Variety	Total No. of tests	No. of years compared	Years on which comparison is based	Average yield
Fulcaster	76	10	1906-1916, except 1909	15.9
Wheedling	40	10	" " " "	14.5
Harvest King	40	10	" " " "	14.3
Fulcaster	52	8	1906-1914, except 1909	16.4
Dawson's Golden Chaff	28	8	" " " "	14.2
Fulcaster	44	7	1906-1914, except 1908, 1909	16.4
Indiana Swamp	24	7	" " " " "	14.9
Fulcaster	64	7	1910-1916	17.7
Economy	32	7	" "	16.9
Missouri Pride	32	7	" "	15.8
Fulcaster	28	5	1906, 1907, 1912, 1913, 1914	13.1
Red Hussar	16	5	" " " " "	10.7
Fulcaster	24	3	1908, 1912, 1913	15.2
Fultz	12	3	" " "	13.1
Fulcaster	20	3	1906, 1907, 1916	13.8
Rudy	12	3	" " "	12.3
Poole	12	3	" " "	12.0
Fulcaster	12	3	1906, 1907, 1908	11.8
Malakoff	8	3	" " "	7.9
Theiss (U. S. 12004)	8	3	" " "	4.7
Fulcaster	24	3	1912, 1913, 1914	15.5
Hungarian	12	3	" " "	12.8
Kharkof	10	3	" " "	9.1
Fulcaster	32	3	1914, 1915, 1916	15.1
Jersey Fultz	16	3	" " "	10.8
Fulcaster	4	2	1906, 1907	9.7
K. B. 2	4	2	" "	7.4
Turkey Red	4	2	" "	6.3
Fulcaster	16	2	1912, 1913	14.7
Pesterboden	8	2	" "	11.1
Beloglina	8	2	" "	8.5
Fulcaster	16	2	1914, 1915	11.7
Nigger	8	2	" "	11.8
Fulcaster	24	2	1915, 1916	14.2
Gypsy	12	2	" "	12.8
Red Cross	12	2	" "	7.6
Mediterranean	12	2	" "	3.0
Miracle	12	2	" "	2.6

winter wheat, and yielded much more per acre. Winter oats did not survive the winter of 1915-1916. No indication of winter-killing was observed with the winter barley.

Winter emmer produced, during this one-year test, 52 bushels per acre. Since emmer is valuable as a feeding crop, it would seem that there may be a place for it in southern Illinois. In a number of feeding tests emmer has been found nearly, if not quite, equal to barley and oats for sheep and cattle.

TABLE 7.—AVERAGE YIELDS OF VARIETIES OF WINTER WHEAT GROWN AT CUTLER, AND PERCENTAGE RATING USING FULCASTER AS A STANDARD (Bushels per acre)

Variety	1902	1903	1904	1905	1906	1907	Percentage rating
Fulcaster (home-grown)	16.4	9.0	15.0	12.8	21.9	23.7	100.0
Harvest King (home-grown)	16.3	14.8	15.6	11.5	20.6	17.7	97.7
Red Fultz (home-grown)	15.3	7.7	15.3	12.6	21.9	18.3	92.2
Eclipse (home-grown)	16.8	5.4	13.7	10.7	22.9	20.2	90.8
Harvest King (Indiana)	10.9	10.5	13.8	11.6	22.5	18.5	88.9
Hybrid Beechwood	11.9	9.0	12.8	11.0	22.7	18.3	86.7
European	11.6	6.4	13.3	11.0	19.2	20.4	82.9
Harvest King (Michigan)	14.3	5.5	12.7	...	...	...	80.4
Poole	12.1	5.2	13.6	...	...	...	76.5
Jones Longberry (home-grown)	16.0	4.3	10.3	...	...	...	75.7
Dawson's Golden Chaff (Michigan)	11.4	6.3	11.2	...	...	...	71.5
Fultz (Tennessee)	10.2	4.0	11.8	...	...	...	64.3
Fultzo-Mediterranean	12.5	1.7	11.4	...	...	...	63.4
Indiana Swamp	11.0	3.2	11.3	...	...	...	63.1
Jones Longberry (Indiana)	6.0	3.5	8.8	...	...	...	45.3
Beardless Rural New Yorker	...	...	...	9.3	18.2	18.0	77.9
K. B. 2	...	...	...	8.7	15.6	16.8	70.4
Turkey Red	...	...	11.4	9.0	13.8	...	68.8

TABLE 8.—COMPARABLE AVERAGE YIELDS OF VARIETIES OF WINTER WHEAT GROWN AT CUTLER USING FULCASTER AS A STANDARD (Bushels per acre)

Variety	Number of years compared	Years on which comparison is based	Average yield
Fulcaster (home-grown)	6	1902-1907	16.5
Harvest King (home-grown)	6	" "	16.1
Red Fultz (home grown)	6	" "	15.2
Eclipse (home-grown)	6	" "	14.9
Harvest King (Indiana)	6	" "	14.6
Hybrid Beechwood	6	" "	14.3
European	6	" "	13.6
Fulcaster (home-grown)	3	1902-1904	13.5
Harvest King (Michigan)	3	" "	10.8
Poole	3	" "	10.3
Jones Longberry (home-grown)	3	" "	10.2
Dawson's Golden Chaff (Michigan)	3	" "	9.6
Fultz (Tennessee)	3	" "	8.7
Fultzo-Mediterranean	3	" "	8.5
Indiana Swamp	3	" "	8.5
Jones Longberry (Indiana)	3	" "	6.3
Fulcaster(home-grown)	3	1905-1907	19.5
Beardless Rural New Yorker	3	" "	15.2
K. B. 2	3	" "	13.7
Fulcaster (home-grown)	3	1904-1906	16.6
Turkey Red	3	" "	11.4

The yields of these winter grains in 1916 were as follows:

Wisconsin Pedigree rye	43.4	Michigan winter barley	17.5
Wing's Black rye	46.8	Winter emmer	52.0[1]
Salzer's winter barley	22.7	Winter oats	0.0

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[1] Based on 30 pounds to the bushel (see U. S. Farmers' Bulletin 466, page 12).

TABLE 9.—CHARACTERISTICS OF VARIETIES OF WINTER WHEAT TESTED AT DEKALB, URBANA, AND FAIRFIELD

Variety	Origin of strain	Bearded or smooth	Color of glume	Color of kernel	Hard or soft	Remarks
Beloglina	Russia	Bearded	White	Red	Hard	Weak straw
Canadian Hybrid	America	Smooth	Silver	Amber	Soft	Coarse straw
Dawson's Golden Chaff	Canada	Smooth	Red	White	Soft	Vigorous, stiff straw
Dawson's Golden Chaff 9-211	Illinois	Smooth	Red	White	Soft	
Dawson's Golden Chaff 9-225	Illinois	Smooth	Red	White	Soft	Vigorous, stiff straw
Early Red Clawson	America	Smooth	Red	Red	Soft	Fairly stiff straw
Economy		Smooth	White	Red		
Fulcaster	America	Bearded	White	Red	Semi-hard	Likely to lodge
Fultz	America	Smooth	White	Red	Soft	Fairly stiff straw
Gold Coin	America	Smooth	Red	White	Soft	Vigorous grower, likely to lodge
Gypsy		Bearded	White	Red	Soft	Medium stiff straw
Harvest King	America	Smooth	Red	Red	Soft	Likely to lodge
Harvest Queen		Smooth	White	White	Soft	Strong straw
Hungarian	Hungary	Bearded	White	Red	Hard	Weak straw
Indiana Swamp	America	Bearded	White	Red	Semi-hard	Medium stiff straw
Jersey Fultz	America	Smooth	White	Red	Soft	
Jones Longberry	America	Bearded	Red	White	Soft	Rather weak straw
K. B. 2	America	Smooth	White	Red	Soft	Medium stiff straw
Kharkof	Russia	Bearded	White	Red	Hard	
Kharkof U. S. 11603	Kansas	Bearded	White	Red	Hard	
Malakoff	Russia	Bearded	White	Red	Hard	Rather short, weak straw, but stronger than Turkey Red
Malakoff 5-458	Illinois	Bearded	White	Red	Hard	
Marvelous	America	Bearded	White	Red		
Mediterranean	Mediterranean Islands	Bearded	Red	Red	Soft	Rather weak straw
Minnesota Reliable	America	Bearded		Red	Hard	Stiff straw
Missouri Pride	Illinois	Smooth				
Native	Illinois	Bearded				
Nigger	America	Bearded	White	Red	Soft	Medium stiff straw
Padi	Russia	Smooth		Amber	Soft	
Pesterboden	Hungary	Bearded	White	Red	Hard	Small straw, rather weak

TABLE 9.—*Concluded*

Variety	Origin of strain	Bearded or smooth	Color of glume	Color of kernel	Hard or soft	Remarks
Poole		Smooth	Red	Red	Soft	Likely to lodge
Red Cross	America	Smooth	White	Amber	Semi-soft	Medium stiff straw
Red Hussar		Bearded	White	Red	Hard	Weak straw
Red Russian	America	Smooth		Red		
Red Wave	America	Smooth	Red	Red	Soft	Fairly stiff straw
Rudy	America	Bearded	White	Red	Soft	Medium stiff straw
Salzer's Hardy Northern	America	Bearded		Red	Hard	
St. Louis Prize Winner	America	Smooth	Red	Red	Soft	
Theiss (U. S. 12004)	Hungary			Red	Hard	Lodges
Turkey Hybrid 402	Illinois	Bearded	Red	White	Soft	Medium tall, medium stiff straw
Turkey Hybrid 509	Illinois	Smooth	White	White	Soft	Rather small, short, medium stiff straw
Turkey Red	Russia	Bearded	White	Red	Hard	Short, fine, weak straw
Turkey 9-233	Illinois	Bearded	White	Red	Hard	
Turkey Red, Native	Illinois	Bearded	White	Red	Hard	
Wheedling	America	Smooth	White	Red	Soft	
Wheedling 5-464	Illinois	Smooth	White	Red	Soft	
Wisconsin 18	America	Bearded				
World's Champion	America	Bearded	White	Red	Hard	
Worley's Smooth	Illinois	Smooth				

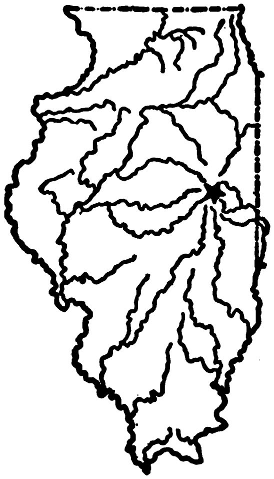
UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

BULLETIN No. 202

IS SYMBIOSIS POSSIBLE BETWEEN LEGUME BACTERIA AND NON-LEGUME PLANTS?

By THOMAS J. BURRILL AND ROY HANSEN



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FOREWORD

This bulletin reports the last work of Thomas Jonathan Burrill, who in 1880, thru studies of pear blight, first experimentally proved the fact that plant diseases are sometimes caused by bacterial invasion.

Symbiotic relationships early attracted the attention of Dr. Burrill, especially the relationship existing between certain nitrogen-gathering bacteria and legumes. In those days every discovery gave rise to new and fundamental questions, and the query whether such relation is necessarily confined to legumes was always in his mind, and was put aside only by the urgency of pressing duties.

When after retirement from active service, opportunity came to Dr. Burrill for following his inclination, his attention at once reverted to the old-time problem, and he fitted up a laboratory and employed an assistant for its study. Here he devoted the last three years of his life, and here the call came suddenly on April 14, 1916, forty-eight years to a month after his coming to the University of Illinois.

Especial credit is due the junior author for his faithful and hopefully successful attempt at accurately reporting the work as planned by his chief, and so far as is humanly possible correctly interpreting his ideas and convictions.

In this difficult task Mr. Hansen has been aided by Dr. A. L. Whiting with some special knowledge of the technical material involved, and by Professor C. F. Hottes, for a quarter of a century Dr. Burrill's close associate, who has read the manuscript with the view of insuring that so far as possible the spirit and thought of the pioneer investigator is expressed.

E. Davenport
Director

IS SYMBIOSIS POSSIBLE BETWEEN LEGUME BACTERIA AND NON-LEGUME PLANTS?

BY THOMAS J. BURRILL, PROFESSOR OF BOTANY, EMERITUS, AND
ROY HANSEN, ASSISTANT IN NITROGEN-FIXATION RESEARCH

INTRODUCTION

The work reported in this bulletin deals with an attempt to develop a symbiosis between legume bacteria and non-legume plants similar to that which exists between legume bacteria (*Pseudomonas radicicola*) and legume plants.

Since the demonstration, in 1886, by Hellriegel and Wilfarth of the symbiotic fixation of atmospheric nitrogen by legume plants and certain microorganisms, no crop rotation has been considered rational that does not include a liberal use of legumes. The importance of this discovery to agriculture is generally appreciated. That it is applicable thruout the world makes it of especial value to mankind.

The benefit that would result could other ordinary farm crops be enabled to utilize atmospheric nitrogen would be inestimable; hence the importance of any success in this direction. In attempting to study this question it was fully realized that success might not be attained, but that it was in the realm of possibilities. It was nearly a quarter of a century ago that the first work was done under the direction of the senior author. Since that time a few attempts have been made by other workers to grow legume bacteria on mustard and grasses, but with negative results.

In returning to this problem, the authors found it necessary at first to spend considerable time in acquiring an intimate acquaintance with the organism concerned, especially in regard to its cultivation and identification. Attention was given to the special adaptations, or varieties, of the symbiotic bacteria in order to learn, first, whether these adaptations were constant or subject to change; and second, what factors were responsible for their existence. Histological studies of the nodule were undertaken with the view of learning something of the relations existing between the two symbionts. The nodules of certain non-legume plants (*Ceanothus, Cycas, Elaeagnus,* etc.), said to be concerned in the fixation of atmospheric nitrogen, were given some attention in the hope that perhaps here lay a start. Cross-inoculations of importance and interest were found and are reported as a part of this contribution. Some preliminary trials were made attempting the inoculation of non-legume plants with the legume organism.

Part I.—THE ORGANISM

ISOLATION AND CULTIVATION

Media.—Pseudomonas radicicola was cultivated on many kinds of media differing widely in composition, and it was found that it would thrive on most of them. For plating out, Harrison and Barlow's wood-ash agar was usually used, as it gave more uniform results. Many media were unsuitable for plating, yet permitted growth upon agar slants.

A list of media employed in these experiments for cultivating *Ps. radicicola,* together with the composition and reaction of each, is given in Table 1.

TABLE 1.—COMPOSITION AND REACTION OF MEDIA USED IN CULTIVATING *Pseudomonas radicicola*

Laboratory No.	Medium	Composition		Reaction[a]
100	Wood ash (Harrison and Barlow)	Wood-ash extract (15 gms. ashes to 1 liter tap water) Saccharose Monopotassium phosphate	1000 cc. 10 gms. 3 gms.	Not changed; usually +7° to +10° to phenolphthalein
101	Synthetic (Fred)	Distilled water Dextrose Monopotassium phosphate Magnesium sulfate Sodium chlorid Ferrous sulfate Manganous sulfate Calcium chlorid	1000 cc. 20 gms. 1 gm. .1 gm. Trace " " "	Titrate to +10°
102	Mannite (Ashby)	Distilled water Mannite Dipotassium phosphate Magnesium sulfate Sodium chlorid Calcium sulfate Calcium carbonate	1000 cc. 20 gms. .2 gm. .2 gm. .2 gm. .1 gm. 5 gms.	Not changed
103	Synthetic (Spratt)	Distilled water Cane sugar Dipotassium phosphate Magnesium sulfate Calcium carbonate	100 cc. 1 gm. .5 gm. .02 gm. .1 gm.	Titrate to +10°
104	Asparaginate (Conn)	Distilled water Sodium asparaginate Dextrose Magnesium sulfate Ammonium phosphate[b] Calcium chlorid Potassium chlorid Ferric chlorid	1000 cc. 1 gm. 1 gm. .2 gm. 1.5 gms. .1 gm. .1 gm. Trace	Not changed; usually +6° to +8°

[a] Fuller's scale in all cases.

[b] Used in place of mono-ammonium phosphate.

TABLE 1.—*Continued*

Laboratory No.	Medium	Composition	Reaction
105	Beef broth	Tap water 1000 cc. Witte's peptone 10 gms. Beef extract (Liebig's) 5 gms.	Titrate to +10°
106	Legume extract, using bean plant	Extract of bean plant (Heat 100 gms. roots and stems in 1 liter tap water ½ hour at 60° C.) 1000 cc. Cane sugar 20 gms.	Titrate to +10°
107	Bean-extract peptone	Same as 106, plus 1 percent peptone (Witte's)	Titrate to +10°
108	Legume extract, using sweet clover	Sweet-clover extract 1000 cc. Cane sugar 20 gms.	Titrate to +10°
109	Sweet-clover-extract peptone	Same as 108, plus 1 percent peptone	Titrate to +10°
110	Tomato infusion	Tomato extract (100 gms. plant substance to 1 liter water) 1000 cc. Cane sugar 20 gms.	Titrate to +10°
111	Tomato-infusion peptone	Same as 110, plus 1 percent peptone	Titrate to +10°
200	Wood-ash agar	Same as 100, plus 1 percent agar	Not changed
201	Synthetic agar (Fred)	Same as 101, plus 1 percent agar	Titrate to +10°
202	Mannite agar (Ashby)	Same as 102, plus 1 percent agar	Not changed
203	Synthetic agar (Spratt)	Same as 103, plus 1 percent agar	Titrate to +10°
204	Asparaginate agar	Same as 104, plus 1 percent agar	Not changed
205	Beef-broth agar	Same at 105, plus 1 percent agar	Titrate to +10°
206	Bean-extract agar	Same as 106, plus 1 percent agar	Titrate to +10°
207	Bean-extract-peptone agar	Same as 107, plus 1 percent agar	Titrate to +10°
208	Sweet-clover-extract agar	Same as 108, plus 1 percent agar	Titrate to +10°
209	Sweet-clover-extract-peptone agar	Same as 109, plus 1 percent agar	Titrate to +10°
210	Tomato-extract agar	Same as 110, plus 1 percent agar	Titrate to +10°
211	Tomato-extract-peptone agar	Same as 111, plus 1 percent agar	Titrate to +10°
300	Wood-ash gelatin	Same as 100, plus 12 percent gelatin	Not changed
305	Beef-broth gelatin	Same as 105, plus 12 percent gelatin	Titrate to +10°
420	Potato slant		
421	Tomato-stem slant	Fresh young tomato stems in distilled water	

Isolation.—In isolating the organism the following method adapted from that of Harrison and Barlow[32][a] was used: Where choice is possible select a medium sized nodule appearing young and sound. In cutting it off leave two or three millimeters of the root on both sides of the nodule to permit handling it with forceps. Wash carefully, rinse in distilled water, and drop into a sterilizing fluid made as follows:

Distilled water	500 cc.
Bichlorid of mercury	1 gm.
Hydrocloric acid (C. P.)	2.5 cc.

Shake the nodule violently in this solution for one or two minutes, after which wash it three times with sterile distilled water. Then cover with about 1 cc. of sterile distilled water and crush with a heavy glass rod, previously flamed and cooled. Pour two or three drops of the cloudy suspension into a test tube of ash agar[b] at 45° C. Inoculate a second tube of the agar with five loops from the first, and pour plates. When a large nodule is used, inoculate the first tube with five loops of the suspension, and inoculate the second tube with five loops from the first, and pour plates. Only two plates are poured; a third was found unnecessary. Incubate plates at from 20° to 25° C. Replating is usually unnecessary, altho it is a safe practice with questionable plates. If the sterilization and washing are carefully done, foreign organisms seldom appear.

Cultivation.—For keeping stock cultures ash agar was used. Transfers were made once a month, tho cultures may easily be kept six weeks or two months between transfers. Plate colonies should be large enough for transfer in six to fourteen days, depending upon the host plant used and other conditions.

MORPHOLOGY

Agar Colonies.—In general the colonies appearing on agar plates may be divided into two types, buried and surface colonies.

Buried colonies are small and submerged, most frequently lens, or spindle shaped, with smooth and even edges. They are quite opaque, granular in structure, and in color are cream to a chalk white. They increase slowly in size, eventually appearing on the surface of the agar as surface colonies, when the growth becomes rapid. The lens colonies, however, remain visible for many days in the center of the new growth.

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[a] Superior figures are used to indicate the literature citations having special reference to this work which are given in the bibliographies.

[b] Obtain ashes from thoroly burned hard wood and run thru a fine sieve. (Little difference was found in different lots of ashes.) Use 15 grams to one liter of tap water and bring to a boil over a free flame, stirring at intervals. Allow solution to stand from five to ten minutes, then filter thru a double filter. To one liter of ash extract add 10 grams of saccharose, 3 grams of KH_2PO_4, and 10 grams of agar. Autoclave for fifteen minutes, filter thru absorbent cotton, and proceed as with other media. The reaction usually was +7° to +10° (Fuller's scale) to phenolphthalein, and was never changed.

Surface colonies originate at or near the surface of the agar or develop from buried colonies. They are drop-form, watery, mucilaginous (in appearance, tho not always to the touch), gray-white to pearly white in color, glistening, and semitranslucent to opaque. The edges are smooth and even. Under the low power the interior is granular. They frequently attain considerable size, a centimeter or more in diameter.

Plates made direct from the nodule lack uniformity to a marked degree. The undiluted plate (first plate) begins to show a few colonies in two to four days. These colonies become extremely large in a very short time, their rapid growth being due to small pieces of nodule tissue or to clumps of bacteria carried over into the agar (see Plate I). In five or six days numerous colonies begin to make their appearance, most of them as submerged colonies, which later grow to the surface.

The dilution-plate (second-plate) colonies are always extremely slow in growth. Generally colonies are large enough for transfer in six to fourteen days, tho plates should not be discarded for two or even three weeks.

The rate of growth of colonies also varies with the organisms of different nodules (see Plate II). Among the fast growers are the organisms from the pea (*Pisum*), vetch (*Vicia*), lentil (*Lens*), sweet pea (*Lathyrus*), bean (*Phaseolus*), lupine (*Lupinus*), wild bean (*Strophostyles*), clover (*Trifolium*), sweet clover (*Melilotus*), alfalfa (*Medicago*), and fenugreek (*Trigonella*). The organisms appreciably slower in growth are those from the cowpea (*Vigna*), Japan clover (*Lespedeza*), tick trefoil (*Desmodium*), acacia (*Acacia*), partridge pea (*Cassia*), false indigo (*Baptisia*), dyer's greenweed (*Genista*), peanut (*Arachis*), soybean (*Glycine*), and hog peanut (*Amphicarpa*).

The Bacteria.—The life cycle of *Pseudomonas radicicola* from the soil thru the nodule and back to the soil is clouded in doubt because of the extreme variability of the organism under apparently the same conditions. While it has been isolated from soil (see Lipman[41 42]), there is no clue to the form in which it existed in the soil.

Observation of cowpea nodules showed that in the very young nodules there is considerable variation in size and shape of the organisms. Many of the small, oval forms, the swarmers described by Beyerinck,[9] are found. These forms and the normal rods predominate. Large club-shaped bacteroids are frequent; the characteristic branched forms are not so numerous. The bacteroids are best demonstrated when the young nodule is just beginning to show a reddish interior. At this stage they are extremely large and contain the maximum staining substance (see Plate III). The characteristic X and Y forms occur in great numbers; they show considerable vacuolation and unevenness in staining, especially when stained with carbolfuchsin.

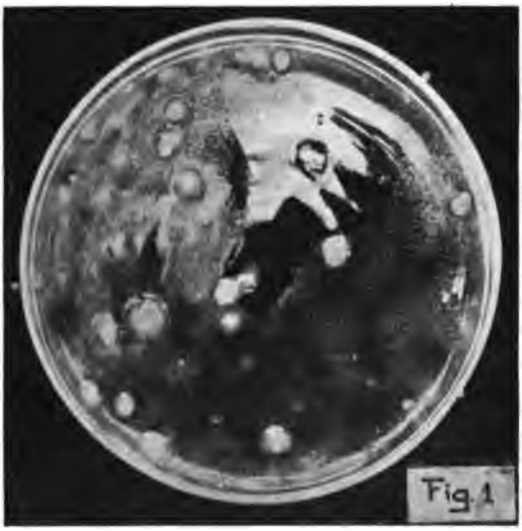

Fig. 1

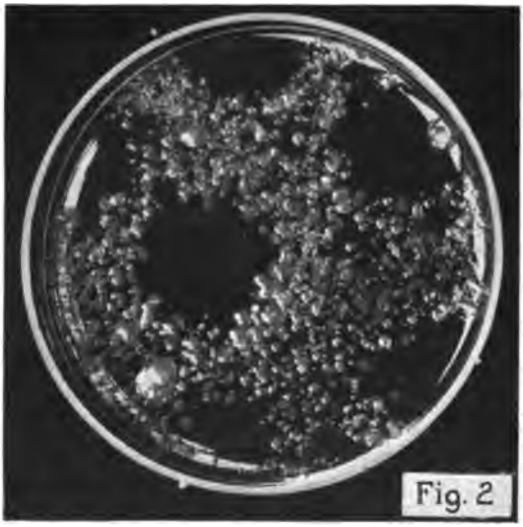

Fig. 2

PLATE I

Fig. 1.—Ash-agar plate from bean (*Phaseolus vulgaris*), showing giant colonies in a thickly seeded plate

Fig. 2.—Ash-agar plate from perennial pea (*Lathyrus latifolius*); the clear spaces are due to sterilizing fluid carried over with pieces of nodule tissue

In the old, decomposing nodule the bacteroids are extremely vacuolated and ghost-like, showing small, oval, deep-staining bodies within. The inference is that these bodies are motile swarmers, which later free themselves from the ghost-like capsules, rather than bud off, as has been described by some writers. Frequently the swollen rods have a beaded appearance with unstained bands or areas. A few motile rods may sometimes be seen in hanging drops in this stage, and sometimes a bacteroid is seen to oscillate as tho swung about by some propelling force in one end. Division of the bacteroids into bacilli, as represented by Dawson,[23] may also occur.

When first plated out, the young colonies consist of small rods which show considerable variation in length. No bacteroids are present, tho the rods are sometimes slightly club-shaped and sometimes show vacuolation. However, they never attain the size of bacteroids. With frequent transfers the rods become quite uniform in size and stain deeply and evenly, especially with aniline-gentian-violet.

In very old cultures (three months on ash agar, without transfer) the small, oval swarmers and the normal rods predominate, tho a few club-shaped and a few branched bacteroids are found. The bacteroids produced upon artificial media[a] are never so large nor so numerous as those seen in mounts direct from a young nodule.

Staining.—The organisms do not stain well with ordinary aniline stains. Carbol-fuchsin and aniline-gentian-violet (used steaming) are the most satisfactory stains. Tho carbol-fuchsin was preferred, aniline-gentian-violet stains were always used as checks, because the former stain accents the vacuolated appearance, particularly in bacteroids. Carbol-fuchsin is especially useful in staining bacteroids direct from the nodule and also old agar cultures. Kiskalt's amyl-gram stain, described by Harrison and Barlow,[32] is useful since the amyl alcohol clears up the field, leaving the bacteria stained, tho not so intensely. This stain, however, should not be considered a means of identifying *Ps. radicicola.*

Bacteroids.—While *Ps. radicicola* produces no spores, it produces bacteroids which are very evidently more resistant than the normal rods. Unfavorable conditions, such as unsuitable media, infrequent transfer, or addition of caffein to the medium, cause their appearance. This is in accord with what takes place in the nodule. In the growing nodule, when development is most rapid, the bacteroids are at their maximum; they enable the organisms to multiply rapidly in spite of the resistance offered by the plant cells. Transferred to favorable media from this stage the normal uniform bacilli are produced. The bacteroid, then, must be regarded as a normal and a very necessary stage in the life of the organism. Its significance in the actual fixation of nitrogen, however, is pure speculation.

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[a] From the writers' observations this is equally true of the bacteroids produced by adding caffein to a legume-extract-agar medium, according to the method of Zipfel[77] and Fred.[26]

Motility.—The motility of the organism is best seen in young agar-slant cultures, twenty-four to forty-eight hours old. The bacteria dart about with amazing rapidity, now tumbling end over end, now spinning violently on the shorter axis, and then sweeping across the field in a darting, jerky course.

Flagella.—Owing to the gum or slime produced by the organism, the demonstration of flagella is especially difficult. The lack of agreement among investigators as to the number is shown in Table 2. The organisms reported by these investigators were all the most abundant producers of gum.

TABLE 2.—RESULTS OF PREVIOUS WORK UPON FLAGELLA STAINS

Investigator	Source of organism	Flagella	Remarks
Beyerinck 1888		One polar flagellum	Inferred during slow motility and not seen
Smith, R. G.[20] 1899		Exceedingly thin, single, terminal flagellum about 2 microns long and bearing upon the distal end a tuft, like the lash of a whip	One photomicrograph
Harrison and Barlow 1907	Hairy vetch (*Vicia villosa*) Perennial pea (*Lathyrus sativus*) Bean (*Phaseolus vulgaris*).	Single polar flagellum	Several figures; mucilage, or negative method, by which slime is stained leaving flagella unstained; discredited by Kellerman
De Rossi[30] 1907	Broad bean (*Vicia faba*)	Bacillus	No figures; describes white, non-liquefying, non-infectuous intruder which has a polar flagellum
De Rossi[33] 1909	White clover (*Trifolium repens*) and other clovers	8 to 10 flagella; peritrichic	One photomicrograph of *Trifolium repens;* very good
Kellerman 1912	Garden pea (*Pisum sativum*) Lima bean (*Phaseolus lunatus*) Alfalfa (*Medicago sativa*)	Flagella fairly numerous; peritrichic	Three photomicrographs, none of which is convincing
Zipfel 1912		Numerous flagella; peritrichic	No figures
Prucha[43] 1915	Canada field pea (*Pisum sativum arvense*)	Peritrichic; largest number observed was six, but there may be more	No figures

Organisms from red clover (*Trifolium pratense*), broad bean (*Vicia faba*), hairy vetch (*Vicia villosa*), common bean (*Phaseolus vulgaris*), sweet clover (*Melilotus alba*), alfalfa (*Medicago sativa*), field pea (*Pisum arvense*), and sweet pea (*Lathyrus odoratus*) were stained for flagella, using several methods, but the gum stained so heavily that none could be seen. The production of gum by the organism, as will be shown later, depends more upon the plant species from which it is isolated than upon the culture medium. Attention was then turned to the organisms making less vigorous growth, which produce less gum. Successful stains were made of the organisms from cowpea (*Vigna sinensis*), tick trefoil (*Desmodium canescens*), dyer's greenweed (*Genista tinctoria*), velvet bean (*Mucuna utilis*), peanut (*Arachis hypogoea*), wild indigo (*Baptisia tinctoria*), Japan clover (*Lespedeza striata*), acacia (*Acacia floribunda*), partridge pea (*Cassia chamaecrista*),[a] soybean (*Glycine hispida*), and hog peanut (*Amphicarpa monoica*).

Loeffler's method of staining was used. The mordant[b] was made up as follows:

Solution of tannin (20 percent in water)	10 parts
Saturated (cold) aqueous solution of ferrous sulfate	5 parts
Saturated alcoholic solution of basic fuchsin	1 part

Transfer the organisms successively several times upon ash agar to hasten the growth. With a platinum needle transfer some of the organisms from the edge of a transfer two or three days old to a small drop of sterile water upon a clean cover slip. Spread slowly and carefully (only a few strokes are necessary), and allow to dry. Cover well with a mordant, bring to a steam, and allow to stand about one minute. Wash carefully with distilled water and apply carbol-fuchsin, bring to a steam, and again let stand one minute.

In examining the slide, look especially near the edges of the smear and close to the "drifts" of bacteria. Slime and stain deposits frequently interfere, tho not seriously. The organism has a single polar flagellum (see Plates IV and V). It was noted that the flagellum is rarely attached at the end, but rather at a corner.

CULTURAL CHARACTERISTICS

Ps. radicicola will grow between 0° and 50°C. The optimum temperature is 25° to 28° C., tho it will grow well at room temperature, or 20° to 25°C. The organism is aerobic. The diffused light of the laboratory is not harmful. Even exposure to direct sunlight for several months without transfer did not kill organisms when grown upon favorable media with precautions to prevent evaporation. Under such conditions a temperature of 47°C. in the flask was reached with the thermometer shaded.

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[a] The organisms of these nine plants comprize a single group, i. e., they are indentical, as will be shown later. Isolations, however, were made from the host plants as named. Actually, then, but three distinct varieties were stained—*Vigna, Glycine*, and *Amphicarpa*.

[b] Filter the ingredients separately and mix in the order given. Filter direct upon the cover slip. The mordant is best used fresh.

Slight alkalinity to +20° to +25° acid (Fuller's scale) with phenolphthalein is tolerated; neutral to +10° is best. Growth is generally better in gelatin or agar media than in liquid media of the same composition.

In an agar stab a typical drop-form colony is produced at the surface. A thin, gray growth follows the line of stab.

Maltose as a source of carbon has little if any advantage over saccharose or dextrose. Mannite is also suitable as a source of carbon.

In standard beef broth the growth of the organism is slow. The liquid becomes cloudy, a gray-white ring is formed, and a thin membrane covers the surface. Later a flocculent precipitate settles to the bottom of the tube.

In standard beef-broth gelatin the growth of the organism is at first funnel-shaped and then stratiform. The gelatin slowly liquefies, the process sometimes requiring two or three months for completion. In gelatin stabs the growth sometimes seals over the stab with a drop-form growth and liquefaction does not occur. If inoculated tubes are kept for several weeks at a temperature just allowing the gelatin to remain liquid, upon cooling it will be found that the gelatin refuses to solidify, whereas the gelatin in uninoculated check tubes does solidify. The enzyme causing liquefaction is present.

On ash-agar plates the presence of *Penicillium glaucum,* which occasionally intruded, seemed to benefit the colonies of *Ps. radicicola* that were in close proximity. Ash agar upon which *Penicillium glaucum* had been allowed to grow for two weeks and which had then been sterilized and filtered, had a noticeable advantage over untreated ash agar, especially with the slower growing organisms, such as those of *Vigna, Glycine,* and *Genista.*

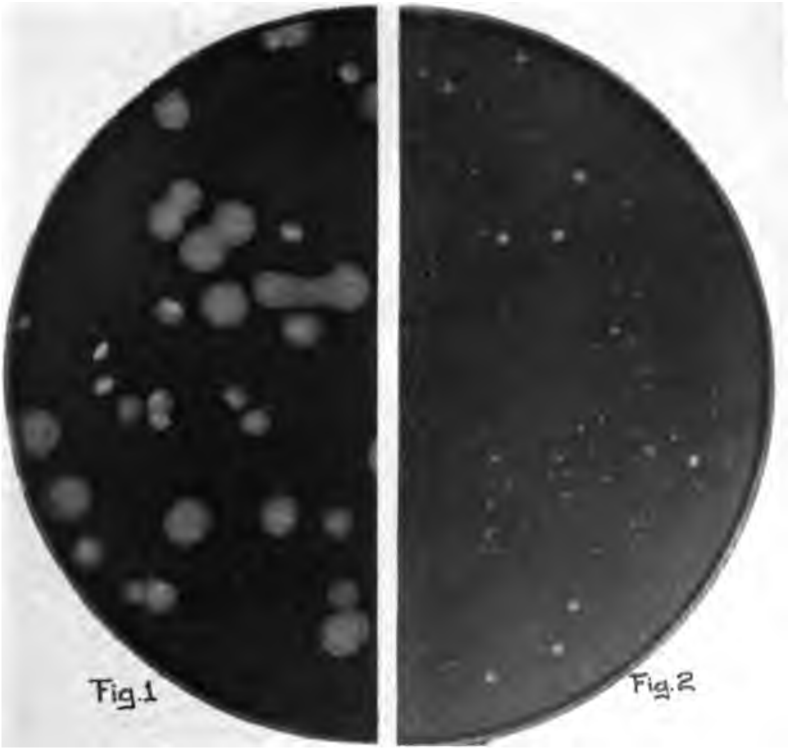

PLATE II

Fig. 1.—Ash-agar plate from pea (*Pisum sativum*), seven days old
Fig. 2.—Ash-agar plate from dyer's greenweed (*Genista tinctoria*), twenty-five days old

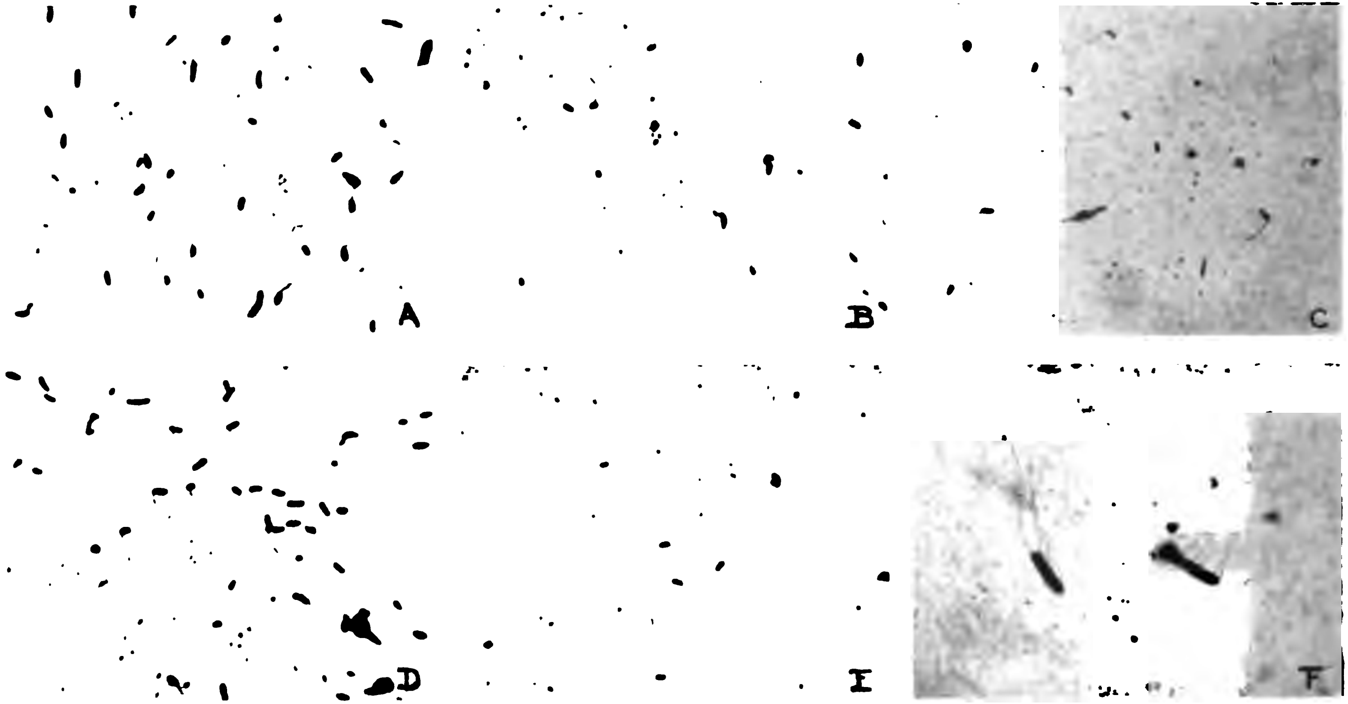

PLATE V

Pseudomonas radicicola, showing polar flagellum: A.—Velvet bean (*Mucuna utilis*) × 1080; B.—Peanut (*Arachis hypogoea*) × 1080; C.—Wild indigo (*Baptisia tinctoria*) × 1080; D.—Hog peanut (*Amphicarpa monoica*) × 1080; E.—Soybean (*Glycine hispida*) × 1080; F.—*B. subtilis*, introduced for comparison × 1080

Part II.—CROSS-INOCULATION: VARIETIES OF NODULE BACTERIA

CROSS-INOCULATION INVESTIGATIONS

It was early recognized that certain legumes require one specific organism for inoculation. For example, to inoculate soybeans it had been found necessary to import soil upon which soybeans had grown, as the bacteria from other legumes were not capable of causing infection. A few cross-inoculations which occur under field conditions were also early recognized. The bacteria of alfalfa and sweet clover[a] were known to be identical, as were those of the cowpea and partridge pea. A third group the bacteria of which were known to be interchangeable included pea, vetch, sweet pea, and lentil.

Several investigators, notably Laurent,[14] Mazé,[21] Moore,[28] and Kellerman,[36] claimed to have produced cross-inoculations which do not occur naturally. Little credence can be given these claims, however, since these men apparently did not fully appreciate what has been frequently referred to as the *ubiquity* of *Ps. radicicola.* No doubt their technic was at fault.

Methods Used in Cross-Inoculation Work.—For testing cross-inoculations bacteria were isolated from as many genera and species of legumes, both wild and cultivated, as could be obtained. Great care was taken in their isolation and in the maintenance of purity. Two methods of testing crosses were used—the pot-culture method and the agar test-tube method of Garman.[38] In the pot-culture method, plants were grown in one-gallon pots of limed white quartz sand watered with a nutrient solution less nitrogen, as described by Hopkins and Pettit.[b] The sand was not sterilized, as it was dry and clean, and sterile so far as legume bacteria were concerned, as proven by the record of the check pots. The pots were washed clean and exposed to sunlight in the greenhouse a week before using, being turned several times. A number of dry, clean pots were always on hand so that no

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[a] Hopkins.[36]

[b] From Hopkins and Pettit Laboratory Manual for Soil Fertility, page 34.

Solution No. 1.—Nitrogen: Dissolve 80 grams of ammonium nitrate in 2500 cc. of distilled water.
Solution No. 2.—Phosphorus: Dissolve 25 grams of mono-calcium phosphate in 2500 cc. of ammonia-free water.
Solution No. 3.—Potassium: Dissolve 50 grams of potassium sulfate in 2500 cc. of ammonia-free water.
Solution No. 4.—Magnesium: Dissolve 20 grams of magnesium sulfate in 2500 cc. of ammonia-free water.
Solution No. 5.—Iron: Dissolve .1 gram ferric chlorid in 250 cc. of ammonia-free water.

Use 10 cc. each of Solutions Nos. 1, 2, 3, and 4, and 1 cc. of Solution No. 5 per liter of water. When nitrogen is omitted the fact is so stated.

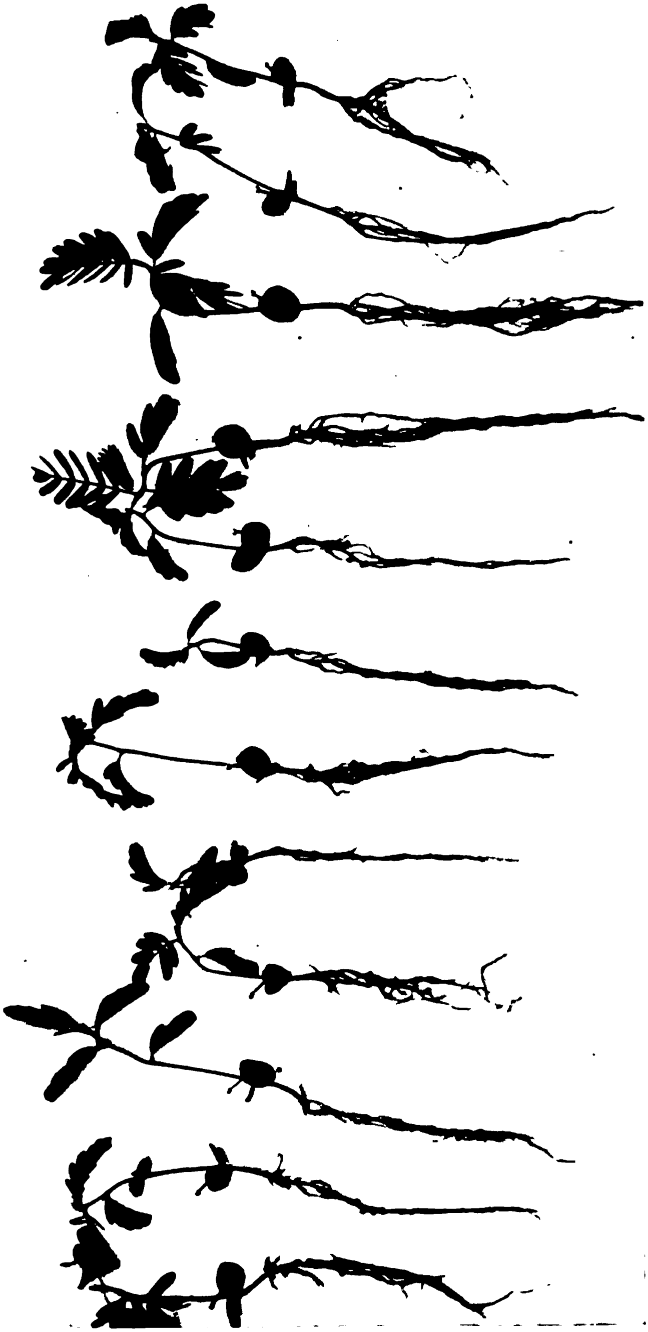

PLATE VI

Seedlings of partridge pea (*Cassia chamaecrista*) inoculated with bacteria from cowpea (*Vigna sinensis*) loss of time resulted when organisms were to be tested. The seeds were sterilized by shaking them violently in Harrison and Barlow's sterilizing fluid, previously described, allowing them to remain in the fluid for ten minutes, and then washing in distilled water. Usually five seeds were planted in a pot. Inoculation was made at the time of planting by adding the contents of an agar slant mixed with sterile distilled water. One pot in each four was left uninoculated as a check.

Occasionally scattered nodules did appear on checks and in pots which when repeated gave negative results. The use of open pots in a greenhouse frequented by many people, together with the presence of occasional insects, etc., cannot but result in some chance inoculations. A chance inoculation, however, is easily distinguished from a true one, for in the former case the nodules are few in number and widely scattered, whereas in a true inoculation the nodules are numerous and clustered in a mass about the tap root. This pot-culture method was used for growing plants with large seeds, such as *Vigna, Glycine, Pisum, Vicia, Lathyrus,* and *Phaseolus.*

In the second method used, that of Garman,[38] seeds were planted in test-tubes (6" x 3/4") containing a medium composed of .65 percent agar in distilled water. No nutrients were added. The agar was inoculated at 42° to 45°C. Seeds (usually three to a tube), sterilized as before, were dropped upon the agar and set apart with a flamed platinum needle. Generally the nodules resulting were not numerous, but where the seeds germinated well, results were always positive and dependable. This method of testing crosses is especially adapted to smaller seeds, such as *Melilotus, Medicago,* and *Trifolium.* Large seeds give trouble, as they are difficult to sterilize.

Vigna × *Cassia.*—The inoculation of the cowpea by bacteria from the partridge pea was first reported by Hopkins.[34] In the other cross-inoculations mentioned above (alfalfa and sweet clover; pea, sweet pea, vetch, and lentil), the plants having a common organism stand in close botanical relationship,[a] while *Vigna sinensis* and *Cassia chamaecrista* are widely separated. Moreover, the former is a plant introduced from Asia, while the latter is a native.

The first cross-inoculation experiments in these investigations were conducted with the partridge pea (*Cassia chamaecrista*), inoculating it as shown in Table 3. Partridge-pea seeds and nodules were obtained from plants found upon virgin prairie in a wild locality where in all probability cowpeas had never been grown. Cultures were obtained from cowpea nodules grown in the greenhouse. Thus the sources of the organisms were wide apart.

The seeds were planted on October 16, 1915, three in each pot; the plants were examined and photographed on November 19 (see Plate VI). The results appear in Table 3. The number of nodules reported

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[a] Engler und Prantl: Die Naturlichen Pflanzenfamilien, III.

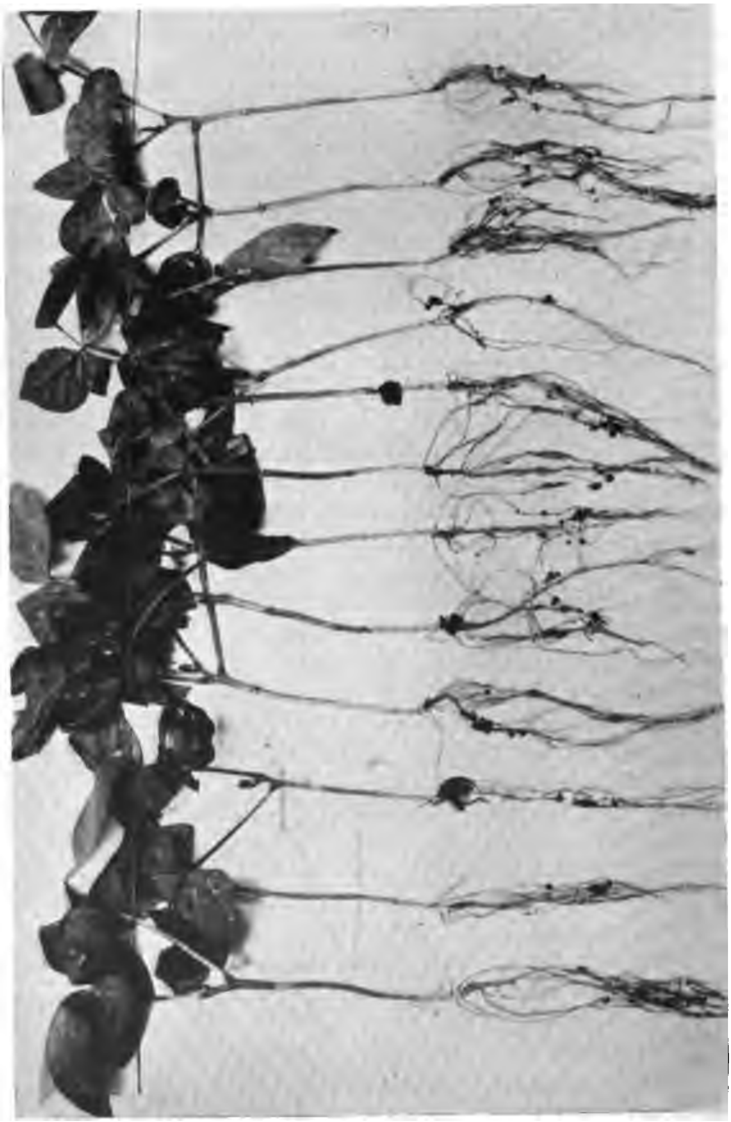

PLATE VII

Seedlings of cowpea (*Vigna sinensis*) inoculated with bacteria from partridge pea (*Cassia chamaecrista*) may be somewhat low, as it is difficult to count the smaller nodules. The checks were examined with great care and found to be free from nodules.

Table 3.—Partridge Pea × Cowpea (*Cassia chamaecrista* × *Vigna sinensis*)

Pot No.	Plant	No. of plants	Source of inoculation	Nodules	Results + or —
4593	Partridge pea	3	Partridge pea No. 4608	17, 15, 9	+
4594	" "	3	" " No. 4609	3, 11, 7	+
4595	" "	3	" " No. 4611	5, 5, 5	+
4596	" "	3	" " No. 4613	3, 3, 11	+
4597	Partridge pea	3	Check	0, 0, 0	—
4598	" "	3	"	0, 0, 0	—
4599	" "	3	"	0, 0, 0	—
4600	" "	3	"	0, 0, 0	—
4601	Partridge pea	3	Cowpea No. 4615	12, 3, 8	+
4602	" "	3	" No. 4617	8, 10, 7	+
4603	" "	3	" No. 4619	7, 8, 6	+
4604[a]	" "	3	" No. 4621	0, 0, 0	—

[a] For some unknown reason the plants in this pot produced no nodules.

The reciprocal was then tried. Five seeds of cowpea were planted in each pot and inoculations made as shown in Table 4. The seeds were planted on November 29, 1915; the plants were examined and photographed on January 3, 1916 (see Plate VII). The results are also shown in Table 4.

Table 4.—Cowpea × Partridge Pea (*Vigna sinensis* × *Cassia chamaecrista*)

Pot No.	Plant	No. of plants	Source of inoculation	Nodules	Results + or —
5023	Cowpea	5	Cowpea Nos. 4398 and 5042	Abundant	+
5024	"	5	" Nos. 4614 " 5039	"	+
5025	"	5	" Nos. 4616 " 5040	"	+
5026	"	5	" Nos. 4618 " 5041	"	+
5027	Cowpea	5	Check	None	—
5028	"	5	"	"	—
5029	"	5	"	"	—
5030	"	5	"	"	—
5031	Cowpea	5	Partridge pea Nos. 4605 and 5035	Abundant	+
5032	"	5	" " Nos. 4607 " 5036	"	+
5033	"	5	" " Nos. 4610 " 5037	"	+
5034	"	5	" " Nos. 4612 " 5038	"	+

Vigna × *Acacia*.—Great interest had been taken in some preliminary trials which had given evidence that a cross exists between cowpea and acacia. Accordingly cowpea plants were inoculated with cultures from six species of *Acacia*, and later with a culture from a seventh. These were *Acacia armata, floribunda, linifolia, longifolia, semperflora,* and a species the nodules of which had been received from

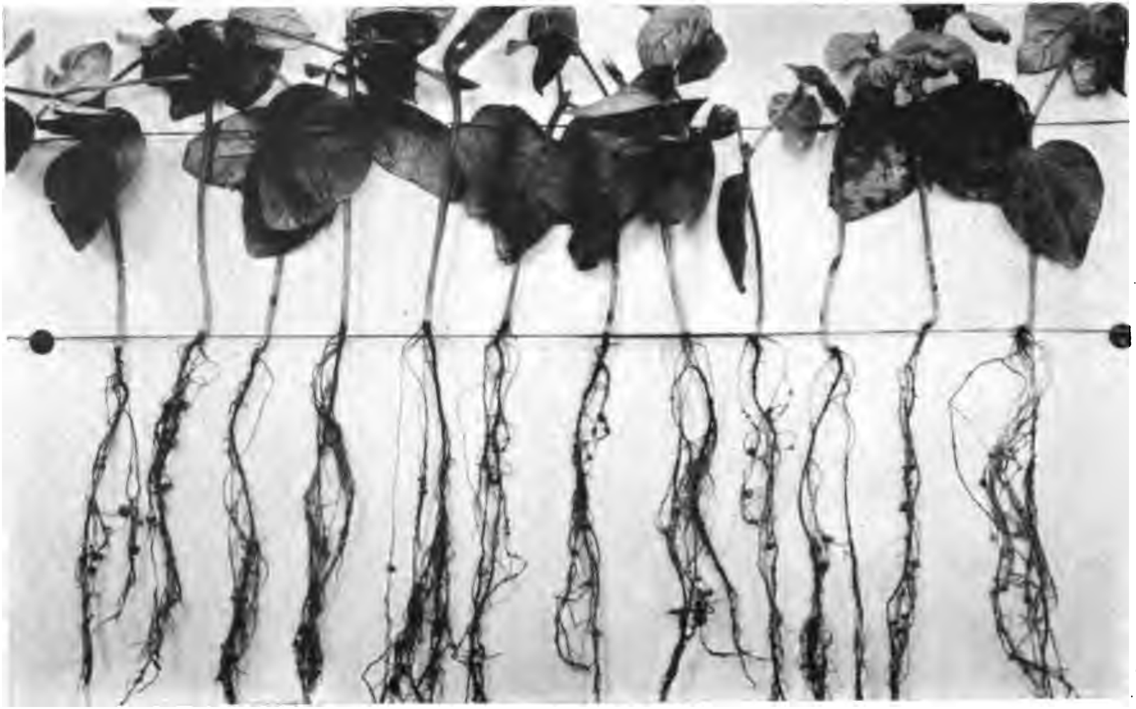

PLATE VIII

Seedlings of cowpea (*Vigna sinensis*) inoculated with bacteria from six species of *Acacia*

California but of which nothing else was known except that it is an ornamental tree. Cultures of the first five species were obtained from nodules of plants grown in the horticultural greenhouse on this campus. Cultures from a seventh species, *Acacia melanoxylon,* which was later grown in this greenhouse, behaved exactly like the other six. Seeds were planted on January 13, 1916; the plants were examined and photographed on February 21 (see Plate VIII). The results are shown in Table 5.

TABLE 5.—COWPEA × ACACIA (*Vigna sinensis* × *Acacia*)

Pot No.	Plant	No. of plants	Source of inoculation	Nodules	Results + or —
5464	Cowpea	5	*Acacia armata* Nos. 5578 and 5649	Abundant	+
5465	"	5	*Acacia floribunda* Nos. 5579 and 5650	"	+
5466	"	5	*Acacia linifolia* Nos. 5580 and 5651	"	+
5467	Cowpea	5	Check	None	—
5468	"	5	"	"	—
5469	"	5	"	"	—
5470	"	5	"	"	—
5471	Cowpea	5	*Acacia longifolia* Nos. 5581 and 5652	Abundant	+
5472	"	5	*Acacia semperflora* Nos. 5582 and 5653	"	+
5473	"	5	*Acacia ?* (from California) Nos. 5583 and 5654	"	+

Cowpea × Several Generic Groups.—Tests made from time to time with the cowpea had shown that infection could be produced with bacteria from eight different generic groups besides the cowpea organism. An experiment was then conducted to bring together the results of these previous trials. The results are given in Table 6.

TABLE 6.—COWPEA (*Vigna sinensis*) × SEVERAL GENERIC GROUPS

Pot No.	Plant	No. of plants	Source of inoculation	Nodules	Results + or —
6309	Cowpea	5	Check	None	—
6310	"	5	Acacia (*Acacia melanoxylon*)	Abundant	+
6311	"	5	Lead plant (*Amorpha canescens*)	None	—
6312	"	5	Hog peanut (*Amphicarpa monoica*)	Several	—
6313	"	5	Check	Several	—
6314	"	5	Peanut (*Arachis hypogoea*)	Abundant	+
6315	"	5	Wild indigo (*Baptisia tinctoria*)	Abundant	+
6316	"	5	Partridge pea (*Cassia chamaecrista*)	Abundant	+
6317	"	5	Check	None	—
6318	"	5	Tick trefoil (*Desmodium canescens*)	Abundant	+
6319	"	5	Dyer's greenweed (*Genista tinctoria*)	Abundant	+
6320	"	5	Japan clover (*Lespedeza striata*)	Abundant	+
6321	"	5	Check	None	—
6322	"	5	Common locust (*Robinia pseudo-acacia*)	Several	—
6323	"	5	Velvet bean (*Mucuna utilis*)	Abundant	+
6324	"	5	Cowpea (*Vigna sinensis*)	Abundant	+

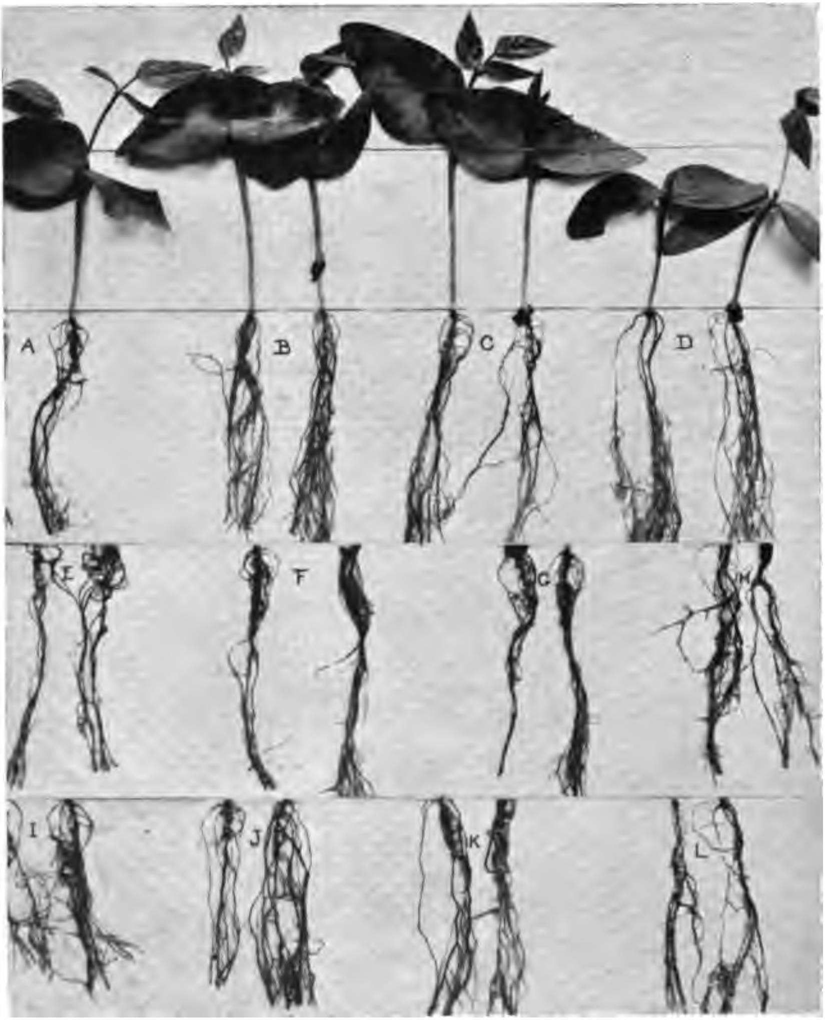

PLATE IX

Seedlings of cowpea (*Vigna sinensis*) inoculated as follows: A.—Partridge pea (*Cassia chamaecrista*); B.—Tick trefoil (*Desmodium canescens*); C.—Dyer's greenweed (*Genista tinctoria*); D.—Check; E.—Japan clover (*Lespedeza striata*); F.—Velvet bean (*Mucuna utilis*); G.—Cowpea (*Vigna sinensis*); H.—Check; I.—Acacia (*Acacia melanoxylon*); J.—Peanut (*Arachis hypogoea*); K.—Wild indigo (*Baptisia tinctoria*); L.—Check

In Plate IX two plants from each pot are shown; those which were negative have been omitted. The results confirmed those of the earlier tests. The plants in three of the negative pots (those crossed with *Amphicarpa, Robinia,* and a check) had several nodules, but these were no doubt accidental as they were very scattered. In a previous trial, inoculations with *Amphicarpa* and *Robinia* had both given negative results.

Lens × *Several Generic Groups.*—Another set of similar experiments is of interest. Lentils were planted on March 17, 1916, and inoculated with bacteria from several generic groups. The seedlings were examined on April 14. The results are shown in Table 7.

TABLE 7.—LENTIL (*Lens esculenta*) × SEVERAL GENERIC GROUPS

Pot No.	Plant	No. of plants	Source of inoculation	Nodules	Results + or —
6386	Lentil	3	Scarlet runner bean (*Phaseolus multiflorus*)	None	—
6387	”	3	Common bean (*Phaseolus vulgaris*)	None	—
6388	”	3	Trailing wild bean (*Strophostyles helvola*)	None	—
6389	”	3	Perennial pea (*Lathyrus latifolius*)	Abundant	+
6390	”	3	Common garden pea (*Pisum sativum*)	Abundant	+
6391	”	3	Field pea (*Pisum arvense*)	Abundant	+
6392	”	3	Broad bean (*Vicia faba*)	Abundant	+
6393	”	3	Check	None	—

In a similar experiment with seedlings of *Trigonella foenum-graecum,* it was found that they could be infected with the bacteria from *Melilotus alba* and *Medicago sativa.* In fact, many inoculation trials were made with all available bacteria. Many results were negative, as is shown in Table 9.

Tests with Garman's Method.—The cross-inoculation trials made by Garman's method together with the results obtained are shown in Table 8. Four inoculated tubes and one check were used for each culture tested. In Plate X are shown seven cultures tested upon *Medicago sativa* (only one tube of each of the seven series is shown) together with two checks. In all, this photograph represents thirty-five tubes, twenty-eight inoculated and seven uninoculated.

Results of Cross-Inoculation Trials.—Table 9 gives in full the results of the cross-inoculation experiments conducted. All available cultures were tried upon seedlings of *Anthyllis vulneraria* and *Mimosa pudica,* but no nodules were produced. It is assumed that the organisms of these plants are distinct from any of those used.

TABLE 8.—CROSS-INOCULATIONS BY GARMAN'S METHOD

Source of inoculation		Plants					
Common name	Botanical name	Lespedeza (*Lespedeza virginica*)	Black medick (*Medicago lupulina*)	Alfalfa (*Medicago sativa*)	Sweet clover (*Melilotus alba*)	Serradella (*Ornithopus sativus*)	Red clover (*Trifolium pratense*)
Acacia	*Acacia floribunda*	+	—	—	—		—
Lead plant	*Amorpha canescens*	—	—	—	—		—
Hog peanut	*Amphicarpa monoica*	—	—	—	—		—
Peanut	*Arachis hypogoea*	+	—	—	—		—
Wild indigo	*Baptisia tinctoria*	+	—	—	—		—
Partridge pea	*Cassia chamaecrista*	+	—	—	—		—
Tick trefoil	*Desmodium canescens*	+	—	—	—		—
Tick trefoil	*Desmodium illinoense*	+	—	—	—		—
Dyer's greenweed	*Genista tinctoria*	+	—	—	—		—
Soybean	*Glycine hispida*	—	—	—	—	—	—
Sweet pea	*Lathyrus odoratus*	—	—	—	—		—
Lespedeza	*Lespedeza virginica*	+	—	—	—		—
Japan clover	*Lespedeza striata*	+	—	—	—		—
Wild lupine	*Lupinus perennis*	—	—	—	—		—
Yellow trefoil or black medick	*Medicago lupulina*	—	+	+	+		—
Alfalfa	*Medicago sativa*	—	+	+	+		—
White sweet clover	*Melilotus alba*	—	+	+	+		—
Wild yellow sweet clover	*Melilotus indica*	—	+	+	+		—
Yellow sweet clover	*Melilotus officinalis*	—	+	+	+		—
Velvet bean	*Mucuna utilis*	+	—	—	—	—	—
Bean	*Phaseolus vulgaris*	—	—	—	—	—	—
Pea	*Pisum sativum*	—	—	—	—	—	—
Black or common locust	*Robinia pseudo-acacia*	—	—	—	—		—
Trailing wild bean	*Strophostyles helvola*	—	—	—	—	—	—
Red clover	*Trifolium pratense*	—	—	—	—		+
Fenugreek	*Trigonella foenum-graecum*	—	+	+	+		—
Hairy vetch	*Vicia villosa*	—	—	—	—		—
Cowpea	*Vigna sinensis*	+	—	—	—	—	—

TABLE 9.—COMPLETE TABLE OF CROSS-INOCULATIONS

Plants		Source of inoculation																							
Common name	Botanical name	*Acacia* (seven species)	*Amorpha canescens*	*Amphicarpa monoica*	*Arachis hypogoea*	*Baptisia tinctoria*	*Cassia chamaecrista*	*Desmodium canescens* and *illinoense*	*Genista tinctoria*	*Glycine hispida*	*Lathyrus odoratus* and *latifolius*	*Lens esculenta*	*Lespedeza virginica* and *striata*	*Lupinus perennis*	*Medicago* (four species)	*Melilotus* (three species)	*Mucuna utilis*	*Phaseolus* (three species)	*Pisum arvense* and *sativum*	*Robinia pseudo-acacia*	*Strophostyles helvola*	*Trifolium* (six species)	*Trigonella foenum-graecum*	*Vicia* (five species)	*Vigna sinensis*
Acacia	*Acacia*	+																							
Hog peanut	*Amphicarpa*			+						—	—	—													
Kidney vetch	*Anthyllis*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Peanut	*Arachis*	+	—	—	+	+	+	+	+	—	—	—	+	—	—	—	+	—	—	—	—	—	—	—	+
Partridge pea	*Cassia*	+	—	—	+	+	+	+	+	—	—	—	+	—	—	—	+	—	—	—	—	—	—	—	+
Tick trefoil	*Desmodium*	+	—	—	+	+	+	+	+	—	—	—	+	—	—	—	+	—	—	—	—	—	—	—	+
Soybean	*Glycine*	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sweet pea	*Lathyrus*	—	—	—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	+	—	—	—	—	+	—
Lentil	*Lens*	—	—	—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	+	—	—	—	—	+	—
Lespedeza	*Lespedeza*	+	—	—	+	+	+	+	+	—	—	—	+	—	—	—	+	—	—	—	—	—	—	—	+
Lupine	*Lupinus*	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—
Alfalfa	*Medicago*	—	—	—	—	—	—	—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	+	—	—
Sweet clover	*Melilotus*	—	—	—	—	—	—	—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	+	—	—
Sensitive plant	*Mimosa*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Velvet bean	*Mucuna*									—	—	—					+								+
Serradella	*Ornithopus*	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—	—
Bean	*Phaseolus*	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—
Pea	*Pisum*	—	—	—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	+	—	—	—	—	+	—
Trailing wild bean	*Strophostyles*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—
Clover	*Trifolium*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—
Fenugreek	*Trigonella*	—	—	—	—	—	—	—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	+	—	—
Vetch	*Vicia*	—	—	—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	+	—	—	—	—	+	—
Cowpea	*Vigna*	+	—	—	+	+	+	+	+	—	—	—	+	—	—	—	+	—	—	—	—	—	—	—	+

Based upon the trials made, the nodule organisms are divided into the following groups according as they are interchangeable for the purposes of inoculation:

GROUP I

Mammoth red clover, *Trifolium pratense perenne*
Alsike, or Swedish clover, *Trifolium hybridum*
Crimson clover, *Trifolium incarnatum*
Berseem, or Egytian clover, *Trifolium alexandrianum*
White clover, *Trifolium repens*
Zigzag, or cow clover, *Trifolium medium*

GROUP II

White sweet clover, *Melilotus alba*
Yellow sweet clover, *Melilotus officinalis*
Wild yellow sweet clover, *Melilotus indica*
Alfalfa, *Medicago sativa*
Alfalfa, *Medicago falcata*
Bur clover, *Medicago hispida*
Black medick, or yellow trefoil, *Medicago lupulina*
Fenugreek, *Trigonella foenum-graecum*

GROUP III

Cowpea, *Vigna sinensis*
Partridge pea, *Cassia chamaecrista*[a]
Peanut, *Arachis hypogoea*
Japan clover, *Lespedeza striata*
Slender bush clover, *Lespedeza virginica*
Velvet bean, *Mucuna utilis*
Wild indigo, *Baptisia tinctoria*
Tick trefoil, *Desmodium canescens*
Tick trefoil, *Desmodium illinoense*
Acacia, *Acacia armata*
Acacia, *Acacia floribunda*
Acacia, *Acacia linifolia*
Acacia, *Acacia longifolia*
Acacia, *Acacia melanoxylon*
Acacia, *Acacia semperflora*
Acacia, *Acacia ?*, from California
Dyer's greenweed, *Genista tinctoria*

GROUP IV

Common garden pea, *Pisum sativum*
Field pea, or Canada field pea, *Pisum sativum arvense*
Hairy vetch, *Vicia villosa*
Spring vetch, *Vicia sativa*
Broad bean, *Vicia faba*
Narrow leaved vetch, *Vicia angustifolia*
Vetch, *Vicia daysiecarpa*
Lentil, *Lens esculenta*
Sweet pea, *Lathyrus odoratus*
Perennial pea, *Lathyrus latifolius*

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[a] Cultures isolated from nodules of *Cassia nictitans* and tested on seedlings of *Cassia chamaecrista* and *Vigna sinensis* failed to produce nodules. The cultures had been on hand some time when tried, and it was suspected that an error had been made. At a later time a number of seedlings of *Cassia medsgeri* were grown and inoculated with the *Cassia nictitans* cultures, as well as with bacteria from

GROUP V

Soybean, *Glycine hispida*

GROUP VI

Garden bean, *Phaseolus vulgaris*
Garden bean, *Phaseolus angustifolia*
Scarlet runner bean, *Phaseolus multiflorus*

GROUP VII

Lupine, *Lupinus perennis*
Serradella, *Ornithopus sativus*

GROUP VIII

Hog peanut, *Amphicarpa monoica*

GROUP IX

Lead plant, *Amorpha canescens*

GROUP X

Trailing wild bean, *Strophostyles helvola*

GROUP XI

Black, or common locust, *Robinia pseudo-acacia*

GROUPING BY SEROLOGICAL TESTS AND BY CULTURAL DIFFERENCES

Review of Results with Serological Tests.—In order to throw light upon the kinship among the various nodule bacteria, Zipfel,[37] in 1912, made use of the agglutination method. From his results he concluded that the nodule bacteria were not varieties of the same species, but that distinct species existed.

Klimmer and Krüger[39] two years later used serological tests to distinguish species. They used the agglutination method principally; and complement-binding and precipitation for confirmation and control. Working with organisms from eighteen legume species, they divided the bacteria, according to their methods, into nine species, which they asserted differed sharply from one another.

Simon,[40] in 1914, tested various cultures upon seedlings of several legume species, and compared the results with those obtained by using Zipfel's agglutination method. He found that the results of both methods agreed substantially. His grouping of the nodule bacteria is in general agreement with that of Klimmer and Krüger.[a] He concluded, however, that "the root bacteria of legumes are rather to be conceived as more or less constant adaptations of the species *Bacillus radicicola.*"

Cassia chamaecrista and *Vigna sinensis,* but no nodules were produced. This suggested that perhaps there is more than one adaptation affecting *Cassia.* The evidence is not conclusive, however.

[a] It should be noted that the pure cultures used by Klimmer and Krüger were supplied by Simon.

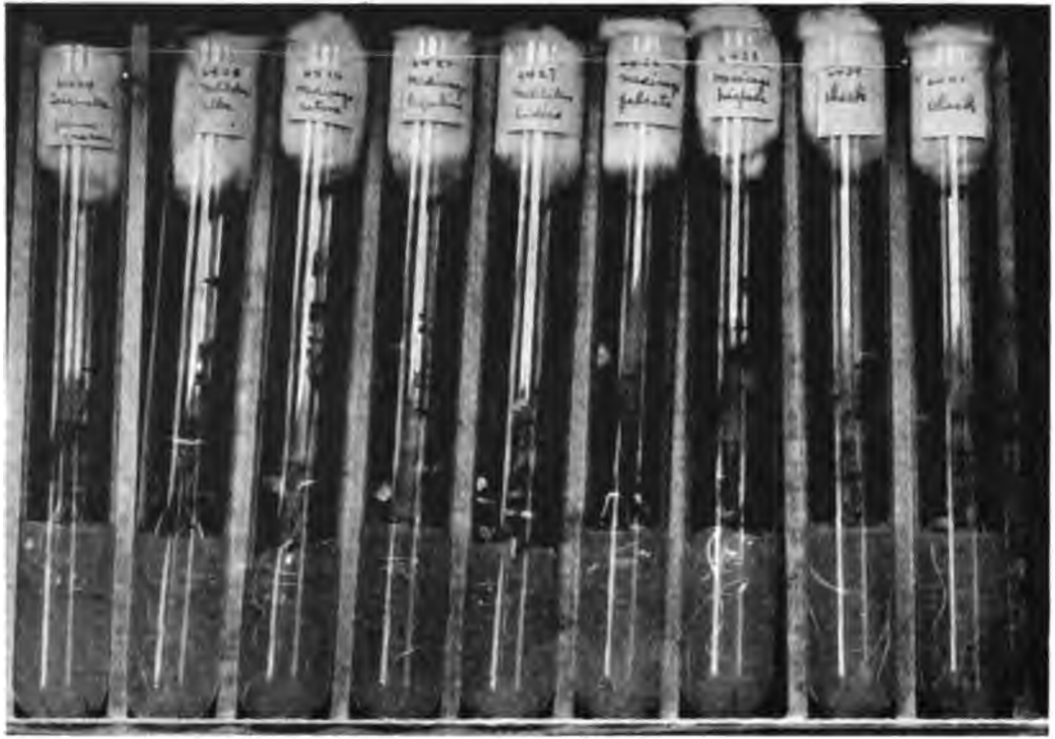

PLATE X

Seedlings of alfalfa (*Medicago sativa*) grown in agar tubes after Garman's method, showing inoculation by several cultures

Grouping by Cultural Differences.—While no serological tests were made in these experiments, a possible basis of distinguishing varieties or species was observed in the striking differences among the organisms upon culture media. When grown upon ash-agar slants, three quite distinct types of growth were noted. The organisms were divided upon this basis into three groups as follows:

Group I.—The organisms are distinguished by the thin, scant growth upon the slant; the streak is a dull gray-white. They are exceedingly slow growers, colonies on agar plates being especially slow. They are not sticky to the touch, and spread quite easily in water upon the cover slip. Flagella are quite easily demonstrated, since there is little gum to interfere. The group includes *Vigna, Cassia, Acacia, Lespedeza, Desmodium, Baptisia, Genista, Arachis, Mucuna, Glycine,* and *Amphicarpa.*

Group II.—The organisms of this group grow more rapidly than those of Group I. The growth is moderate to abundant with but little tendency to spread. The streak is raised, glistening, opaque, and pearly white in color. Tho not usually very sticky to the touch, there is considerable gum, which seriously interferes in attempts to stain flagella. *Melilotus, Medicago,* and *Trigonella* make up this group.

Group III.—The growth of these organisms is very fast, and there is a strong tendency to spread. The streak is watery and semi-translucent, being quite different from the opaque growth of Group II. The surface is not so shiny as in that group. Further, the organisms are quite slimy and usually quite sticky to the touch. The excessive amount of gum prevents staining of flagella and holds the organisms in clumps so that they cannot be spread easily on the cover slip. The organisms of *Vicia, Pisum, Lens, Lathyrus, Trifolium, Phaseolus,* and *Strophostyles* are included in this group.

While the descriptions above apply more directly to growth upon ash agar, the differences hold true for growth on other agar media, especially Fred's synthetic and Conn's asparaginate agar. The latter is especially suited to the organisms of Group I, growth upon it being considerably better than upon ash agar. It was further noted that these differences did not disappear with the aging of the cultures, but on the contrary became more pronounced. Cultures which were two years old showed in young transfers the differences noted in freshly isolated cultures.

Varieties vs. Species.—While the grouping of the various nodule bacteria is perhaps best determined by actual plant inoculations, yet the results of serologic tests show that the various organisms are different and that these differences are permanent. Likewise in certain cultural characteristics herein described we find differences which also are permanent. Furthermore, the adaptations as tested by actual inoculations upon plants are constant. For example, the soybean organism not only retains its individuality as tested by serologic methods and by cultural characteristics, but it also retains its special adaptation to the soybean plant, in spite of imposed conditions designed to break this adaptation. These facts form perhaps a legitimate basis for the belief that distinct species exist among the nodule bacteria. In numerous other characteristics, however, these bacteria are so much alike, and as a whole they differ so widely from any other species of bacteria, that it seems more consistent to regard the adapted forms as varieties of the single species *Pseudomonas radicicola.*

Experiments in cross-inoculation brought out the fact that in many cases in which a single organism is capable of infecting several plant genera, the host plants stand in close botanical relationship. In Group III, however (see page 136), is a striking exception to this. In *Acacia, Cassia,* and *Vigna,* we have each of the three sub-families of the *Leguminosae* represented, yet the same organism produces nodules upon all three. Obviously botanical relationship is not responsible in this case.

Mazé[21] claimed that the reaction of the soil was responsible for the special adaptations. He divided the nodule bacteria into two groups, those infecting plants which have become accustomed to acid soil and those infecting plants which have become accustomed to alkaline soil. By gradually accustoming a bacterium from the alkaline-soil group to an acid medium, he claimed to have so modified it that it would produce nodules upon lupines, which belonged to his acid-soil group. However, observations do not bear out Mazé's statements in regard to the two groups. The reaction of the soil does not appear to have any significance in determining the groups, of which there are certainly more than two. Furthermore, the reaction of artificial media does not break or change the special adaptations, nor is the organism modified at all so far as its power to produce nodules is concerned.

Evidently, then, the adaptation is between the root-sap of the plant and the bacteria. It may be a case of specific enzymes produced by the bacteria, or of differences in the root-sap which cannot be detected by chemical methods.

Part III.—HISTOLOGY OF THE NODULES OF THE LEGUMINOSAE

Technic.—Sections were made, for the most part, from nodules of plants grown in normal soil, for it was desired to study especially the nodules as they occur in nature. When sections from young nodules were desired, however, plants were grown in quartz sand, watered with the nutrient solution.[a]

The paraffin method of imbedding was used entirely. Sections were usually cut five or six microns thick; thinner sections were tried but abandoned owing to the difficulty in getting good mounts. In the earlier attempts, material was fixed by immersing from four to six hours in a picric fixing agent.[b] Haidenhain's iron-haematoxylin was usually used in conjunction with the picric fixative. Sections were mounted in series and stained upon the slides, after removing the paraffin with xylol, etc. The mounts obtained were not entirely satisfactory, but were valuable for comparison with mounts stained otherwise. Differentiation with the ferrous-ammonium-sulfate solution can be carefully controlled, which is the great advantage of this method.

Flemming's method was later adopted for most of the work. Nodules were fixed in Flemming's weaker solution (chrom-osmic-acetic solution), and the triple stain[c] then applied. Sometimes the triple stain was used with material fixed in picric acid, and altho results were not so good as with material fixed in the chrom-osmic-acetic fluid, still very satisfactory mounts were obtained. With haematoxylin mounts, cedar oil was used for clearing; with the triple stain, clove oil was preferred.

Considerable difficulty was experienced with thin sections when the triple stain was used, owing to the rapid loss of stain when dehydrated with ethyl alcohol. Dehydration and differentiation with ethyl alcohol was not wholly unsatisfactory; however, by using amyl alcohol instead of ethyl alcohol, more densely stained mounts were obtained.

For demonstrating starch, slides were stained with Flemming's triple stain and differentiated with ethyl alcohol, removing all excess stain. They were then transferred to distilled water to remove the alcohol, after which they were mounted in distilled water to which a small quantity of Lugol's iodine solution was added. The iodine was not concentrated enough to discolor the field, but gave the characteristic blue to the starch. Water was added during examination when

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[a] See footnote, page 125.

[b] The solution was made up as follows:

Corrosive sublimate	5 gms.
Glacial acetic acid	5 cc.
Saturated solution of picric acid in 70 percent alcohol	100 cc.

[c] Safranin, gentian-violet, orange G.

necessary to prevent drying out. Such mounts are not permanent, but they may be made so by restaining and mounting in balsam, tho the blue color is not retained by the starch.

A useful modification of Flemming's triple stain is to follow the gentain-violet with Lichtgrün[a] instead of orange G.

ORIGIN OF THE NODULE

Whether the active motility of *Ps. radicicola* in certain stages has any bearing upon the infection of the root-hairs, or young roots, of legumes, is not known. The vigorous root system of the *Leguminosae* in general, however, is probably a big factor.

The entrance of the organism into the root thru the root-hair, as described by previous investigators, was not studied in these investigations. According to these workers,[b] the infection first appears as a bright spot at or near the tip of the root-hair. The bacteria gain entrance by dissolving the cell wall, probably thru the agency of an enzyme. Infection is followed by a distinct bending of the root-hair, the response to the irritation set up. The organisms multiply and form a zoogloeal strand, which makes its way down the root-hair into the root-cortex. In the innermost layers of the cortex, the irritation is set up which gives rise to the nodule. The cells are stimulated to rapid growth, a meristem is formed, and the young nodule emerges from the root epidermis as a mass of parenchymal cells. In origin, then, the nodule is similar to the lateral root, but here the similarity ends.

While it is well established that infection takes place in this way, still it is evident that it is not thru the root-hairs alone that the bacteria gain entrance. The root epidermis itself may be penetrated, as with seedlings grown in agar test-tube cultures (Garman's method), in which case no root-hairs are produced. The same is found true of seedlings grown in sand saturated with a nutrient solution and not inoculated until the roots have made several inches of growth. On allowing time for infection and nodule production, it will be found that nodules are produced abundantly around the tap root above the region of root-hairs.

STRUCTURE OF THE NODULE

In Plate XI is shown the gross structure of nodules of *Trifolium pratense* which are well developed but still growing. Fig. 1 represents a longitudinal section near the central part of a nodule. The greater portion, it will be seen, is made up of bacteroidal cells, which occupy

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[a] .5 gram in 200 cc. of alcohol.

[b] Marshall Ward,[8] [13] and Peirce[25] should be consulted. Other important contributions are the following. Woronin,[1] [2] Eriksson,[3] Frank,[4] Beyerinck,[9] Tschirch,[7] Vuillemin,[11] Prazmowski,[6] [12] [15] Schneider,[16] Atkinson,[17] and Dawson.[22] [26]

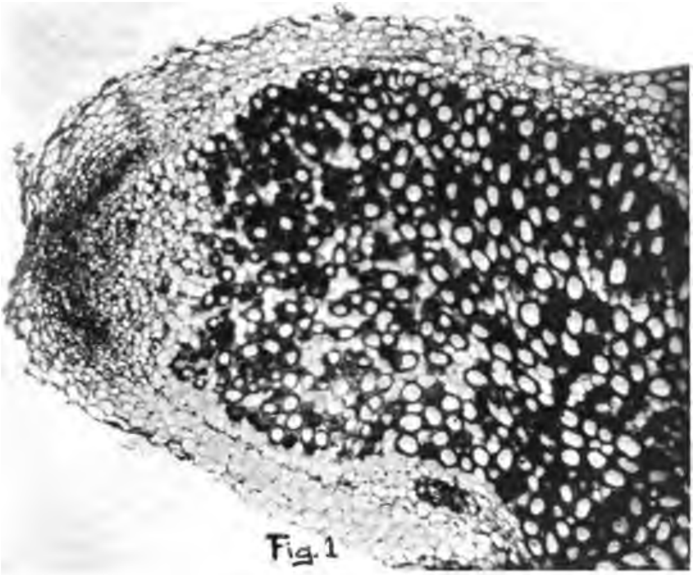


Fig. 1

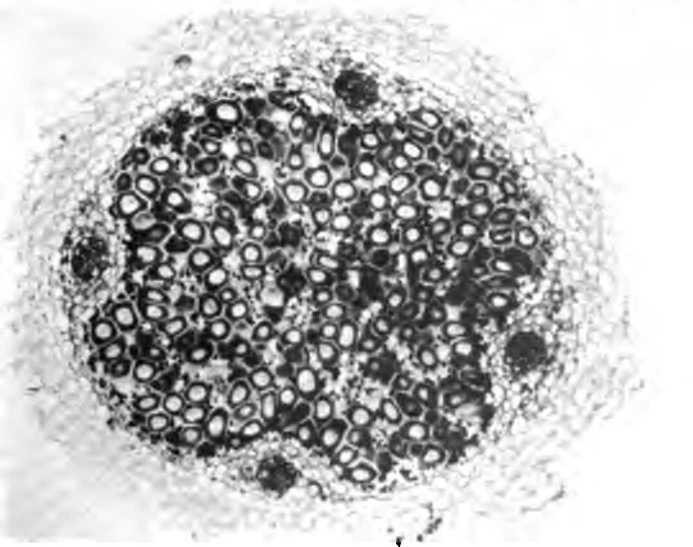


Fig. 2.

PLATE XI

Fig. 1.—Longitudinal section of a nodule of red clover (*Trifolium pratense*) **which was well advanced but still growing, showing vacuolated bacteroidal cells, vascular tissue, nodule cortex, and meristem.** Stained with Flemming's triple stain **with amyl alcohol dehydration** × 100

Fig. 2.—**Cross-section** of a similar nodule of red clover (*Trifolium pratense*). **Stained with Flemming's** triple stain and mounted in dilute iodine solution **to show the starch.** The **fibro-**vascular bundles are especially **prominent** × 100

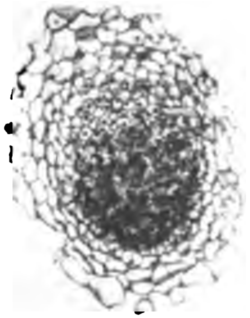


Fig. 1

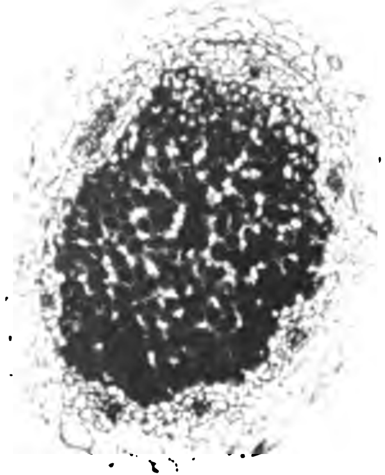


Fig. 2

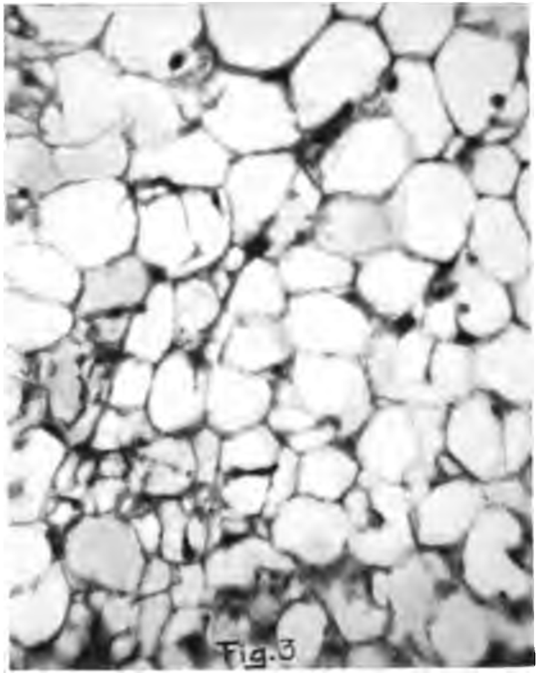
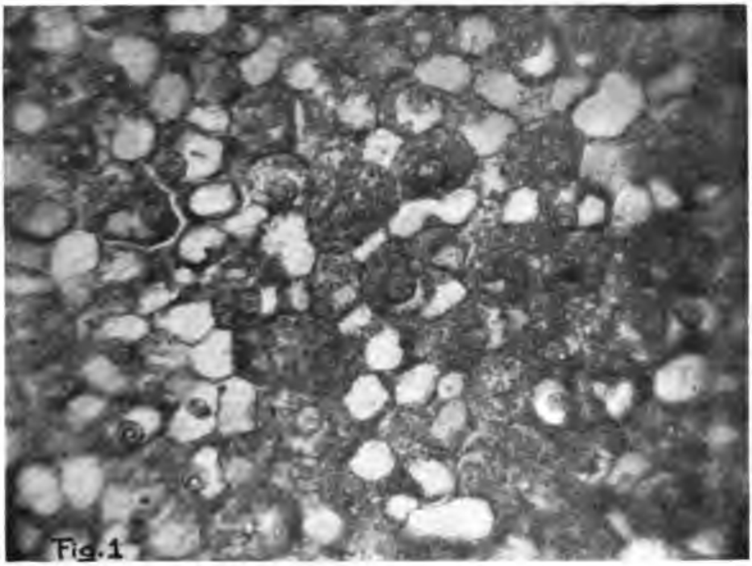


Fig. 3

PLATE XII

Fig. 1.—Cross-section thru the meristem region of a nodule of hairy vetch (*Vicia villosa*) × 100
Fig. 2.—Cross-section thru the same nodule some distance back from the meristem × 100
Fig. 3.—Infection threads in the cortex cells of a nodule of red clover (*Trifolium pratense*) × 1080



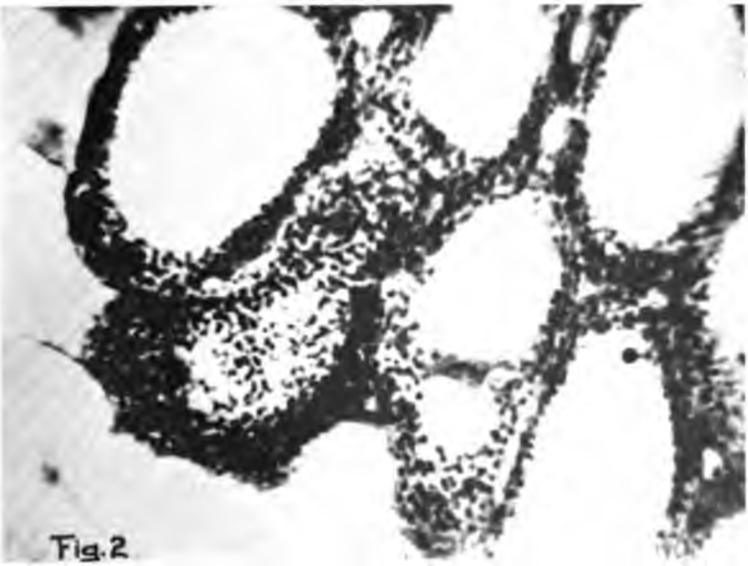


PLATE XIII

Fig. 1.—Young infected cells of a nodule of hairy vetch (*Vicia villosa*) (same as Fig. 2, Plate XII). Stained with Flemming's triple stain. The bacteria do not show distinctly × 430

Fig. 2.—Bacteroidal cells of red clover (*Trifolium pratense*) in a well advanced but growing nodule. Cells have become vacuolated and filled with bacteroids. Flemming's triple stain with amyl dehydration × 1080

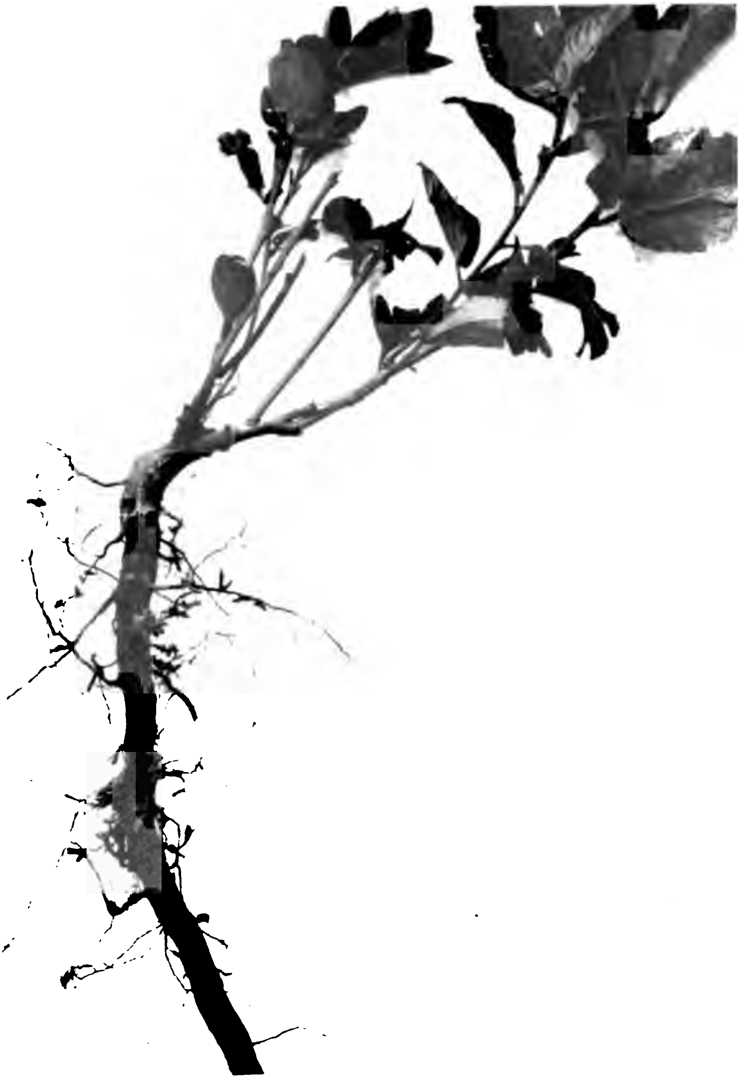


PLATE XIV

Root nodules of *Ceanothus americanus*

the middle area. The fibro-vascular system is immediately outside this, inclosed in the cortex layer of cells. At the tip is a well defined meristem made up of small, rapidly dividing cells, containing large nuclei. Few bacteria or bacteroids are found in the meristem or in the cortex; they are confined mostly to the bacteroidal cells. Aside from possessing bacteroidal tissue, the nodule differs from the lateral root in that it has no central cylinder. Further, it has no root-cap and no epidermis, but is inclosed by a protective band of corky cells.

Fig. 2, Plate XI, shows a cross-section of a nodule of *Trifolium pratense* at about the same stage of development as that shown in Fig. 1. This section was stained with Flemming's triple stain and then mounted in dilute iodine solution in order to show the location and distribution of starch. The fibro-vascular bundles may be seen especially well.

The bacteroidal cells of younger nodules are strikingly different from those of older ones. In the young nodule the cells are full and closely packed. Plate XII shows sections of a young nodule of *Vicia villosa.* Fig. 1 of this plate shows the meristem, and Fig. 2 a section some distance back. The latter figure should be compared with Fig. 2 of Plate XI. These young infected cells are shown more highly magnified (× 430) in Plate XIII, Fig. 1. The cells are filled with cytoplasm in which are dispersed myriads of bacteria. These bacteria occur chiefly as swarmers or as small vacuolated rods, so that it is difficult to resolve them in the cytoplasm. The nuclei are quite prominent.

As the nodule becomes older, the bacteria are more in evidence, the bacteroids becoming especially large and numerous. The nucleus becomes distorted and is pushed to one side of the cell, tho sometimes it disintegrates and disappears entirely, giving way to a large central vacuole, which is inclosed by a band containing mostly bacteroids. Fig. 2, Plate XIII, shows a few cells (× 1080) in which this has taken place. (This figure shows a few cells of Fig. 1, Plate XI, more highly magnified.) It is in this stage of development that the large, branched bacteroids, such as those shown in Plate III, are found.

The fibro-vascular system extends from the meristem region to the base of the nodule, where the elements unite and communicate with the central cylinder of the lateral root. As the nodule becomes older, the bacteria further devastate the cells and probably automatically shut off the food supply from the root, whereupon the nodule decays and sloughs off.

The so-called infection threads (*Fäden,* of Tschirsch; *Infektionschlauche,* of Prazmowski) so frequently found, especially in young nodules, were the objects of much study. Contrary to the opinions of Dawson[23] and Peirce,[25] the infection threads are *not* zoogloeal strands made up of small bacilli, but are solid hyphae-like structures bearing a remarkable resemblance at times to tubes, which in fact some earlier investigators believed them to be (see Plate XII, Fig. 3). No septae were found. The threads were more frequently seen in the meristem or in the cortex cells near the apex of the nodule. The longest one observed in a single section traversed six consecutive cells. Shorter threads were frequently encountered in the bacteroidal tissue. Frequently the threads were found branched, and invariably they were growing directly toward the cell nucleus or sending a branch to it. In passing thru the cell walls the thread becomes peculiarly thickened or flattened, producing a funnel-like appearance. This also occurs when the thread approaches the nucleus.

With the view that the infection threads are not zoogloeal strands composed of separate bacilli, they become more difficult to explain. A possibility is that they are due to unusually stimulated bacteroids or to a number of bacteroids which fail to divide but remain attached with the resorption of the cell wall between. However, this is pure speculation.

Part IV.—NON-LEGUMES SAID TO BE CONCERNED IN THE FIXATION OF ATMOSPHERIC NITROGEN

HISTORICAL

The demonstration by Hellriegel and Wilfarth[5] [10] of the fixation of nitrogen by legume plants and the isolation by Beyerinck of the organism from the legume nodules, stimulated interest in the root nodules found upon non-legume plants. Of the groups of non-legumes which possess these structures, those which have received the most attention are *Ceanothus, Elaeagnus, Alnus, Podocarpus, Cycas,* and *Myrica.*

The earlier investigators[a] for the most part held that nodules were of fungous origin. Arzberger[49] held that the causal agents (*Frankia ceanothi* and *Frankia subtilis*) in *Ceanothus* and *Elaeagnus* were quite similar, but that that (*Frankia brunchorstii*) of *Mryica* was quite different, being of the nature of an *Actinomyces.*

Previous to Arzberger, Hiltner[45] in 1896 claimed a fixation of nitrogen by *Alnus* and *Elaeagnus.* In 1899, Nobbe and Hiltner[46] claimed the same for *Podocarpus,* the nodules of which were said to be due to an endotrophic mycorrhiza.

Bottomley[48] [b] claims to have demonstrated in 1907 the presence of nitrogen-fixing bacteria in the nodules of *Cycas.* In 1912 the same writer[51] reported the isolation of an organism identical with *Ps. radicicola* from *Myrica gale* and claimed fixation of nitrogen by young *Myrica* plants.

In the same year Spratt,[52] working in Bottomley's laboratory, reported a similar isolation from *Alnus* and *Elaeagnus* and also from *Podocarpus.*[53]

More recently Bottomley[54] has reported the isolation of *Ps. radicicola* from *Ceanothus,* and shown the fixation of nitrogen in culture solutions by the organism isolated.

CEANOTHUS AMERICANUS

Attempts to Isolate the Causal Organism.—As *Ceanothus americanus* grows close at hand, material for study was easily obtained. Efforts to isolate a causal organism were persistent, covering a period from early spring to late fall. Nodules in all stages were plated, special effort being made upon the extremely young ones. With ash agar alone ninety plates were poured in duplicate. Legume nodules were frequently plated as checks upon the method, the same procedure being used in each case. Legume nodules nearly always gave good plates; *Ceanothus* nodules failed always. Variation in the seeding of the plates was tried. Sometimes the entire nodule was crushed with several cubic centimeters of sterile water and poured with the plate; sometimes several loops of infusion were used; and sometimes the nodules were cut open and the tissue scraped out for plating. Ash-agar plates were inoculated direct with nodule tissue and with crushed infusion.

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[a] For a review of the subject Arzberger should be consulted.

[b] The paper written in 1907 to which Bottomley refers was not found.

Other media were tried. The list included Fred's agar (No. 201), Ashby's (No. 202), Spratt's (No. 203), beef-broth agar (No. 205), Conn's asparaginate agar (No. 204), *Ceanothus*-extract agar (similar to No. 206), a mixture of *Ceanothus*-extract agar and ash agar, potato agar, oatmeal agar, cornmeal agar, Loeffler's blood-serum agar, and Koch's blood-serum agar. Many plates were poured and many direct slants tried. Liquid media were not extensively employed as this means of isolation is objectionable. However, Spratt's medium (No. 103) and beef broth (No. 105) were tried.

In no case did a typical plate resembling those obtained in plating legume nodules result. For the most part the plates were blank except for an occasional mold or yeast. Bacterial colonies sometimes grew, but never did a single organism persist that upon examination in any way resembled *Ps. radicicola.*

Almost invariably slants made direct from nodule tissue or crushed infusions failed to show growth. As with the plates, there was nothing to suggest a causal agent, either like or unlike *Ps. radicicola.* Little reliance was placed on the liquid cultures; most of them showed no growth.

Nitrogen-Fixation by Ceanothus americanus.—In order to test the fixation of nitrogen by *Ceanothus,* thirteen young plants were washed clean and planted in clean quartz sand to which lime had been added. Seven of the plants were given a nutrient solution without nitrogen, and inoculated abundantly with an infusion of crushed nodules. Six were given the same solution plus nitrogen, but were not inoculated. None of the plants fully recovered or made very vigorous growth. After ten months all those not receiving nitrogen were dead. Two of those receiving nitrogen still survived but were not doing well. All the plants produced nodules.

Seeds of *Ceanothus americanus* were obtained in the fall of 1915. By immersing them in commercial sulfuric acid for ten minutes a germination of about five percent was obtained. Three series of six pots were then filled with white quartz sand and four seedlings planted in each pot. Nutrient solutions were added as shown in Table 10. The plants in Series III were inoculated with an infusion of crushed *Ceanothus* nodule.

After seven months, Series II and III had made a very weak growth; there was no choice between them. Series I also had not made a very vigorous growth, but the plants were noticeably larger and greener than those of the other series. A further observation of im-

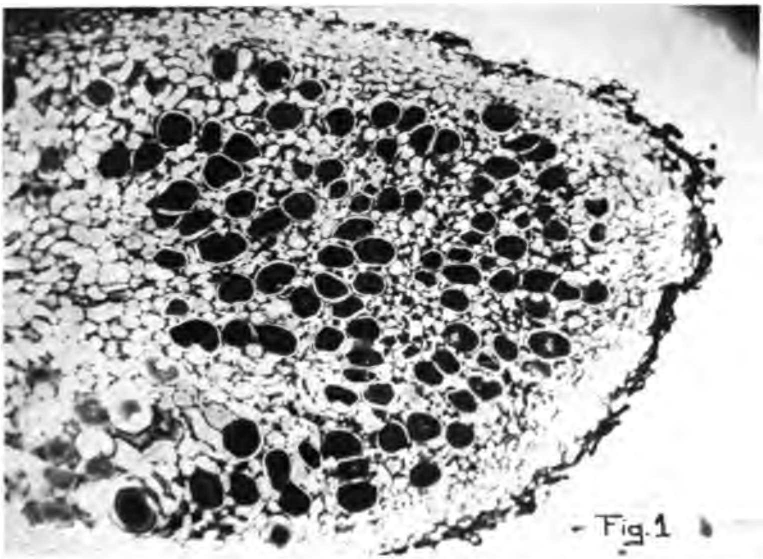

Fig. 1

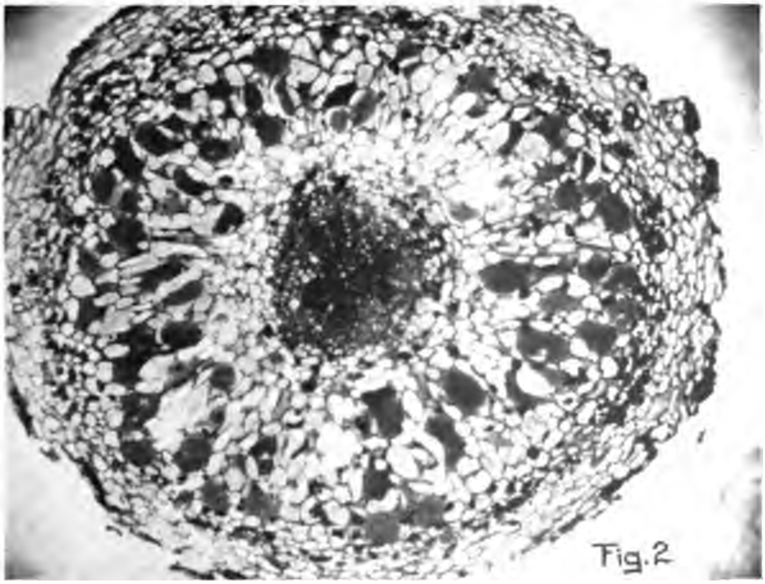

Fig. 2

Plate XV

Fig. 1.—Longitudinal section of a *Ceanothus americanus* nodule, showing parasitized zone. Stained with Flemming's triple stain and mounted in iodine to show the starch × 100

Fig. 2.—Cross-section thru a similar nodule of *Ceanothus americanus*, showing central cylinder, some parasitized cells, starch, etc. × 100

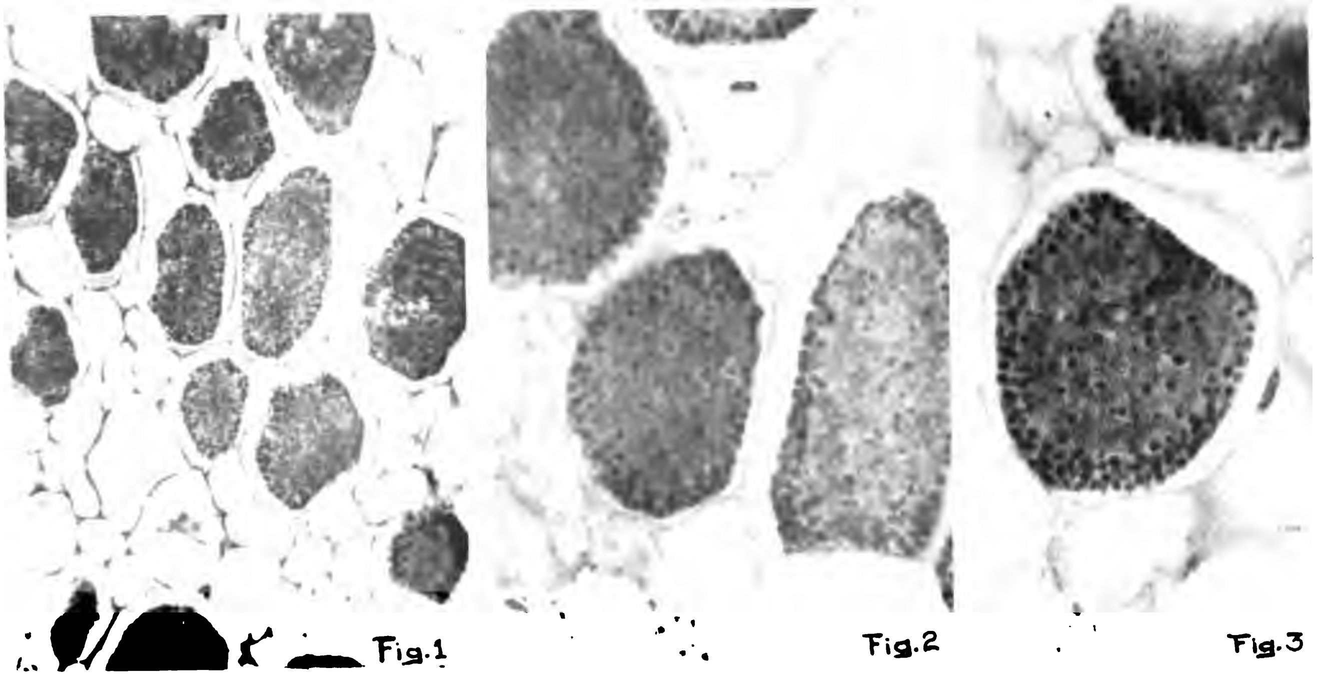

PLATE XVI

Fig. 1.—Parasitized cells of a *Ceanothus americanus* nodule × 430
Figs. 2 and 3.—Same more highly magnified. There is a strong suggestion of fungous threads, especially in Fig. 3 × 1080

portance was that Series III had no nodules, in spite of the fact that the young seedlings had been abundantly inoculated with an infusion of crushed nodules.

TABLE 10.—EXPERIMENT IN NITROGEN-FIXATION WITH SEEDLINGS OF CEANOTHUS AMERICANUS

Series	No. of plants	Inoculation	Treatment	Nodules
I	24	None	Full nutrient solution	None
II	24	None	Nutrient solution without nitrogen	None
III	24	Infusion of crushed *Ceanothus* nodule	Nutrient solution without nitrogen	None

While the evidence submitted is not conclusive, it at least throws doubt upon the ability of *Ceanothus* to fix atmospheric nitrogen. Apparently either quartz sand is not favorable or the solutions used were not best suited to this plant. It must be considered, however, that *Ceanothus* is a slow-growing shrub, and hence the demonstration would not be so easy as with quick-growing legumes.

Histology of the Nodules of Ceanothus americanus.—An extensive description of the nodules of *Ceanothus americanus* is not intended here, but it is desired to show enough of the structure so that a fair comparison with legume nodules may be made. For further information Bottomley, Spratt, and especially Arzberger, should be consulted.

In Plate XIV are shown some *Ceanothus* nodules. When extremely young, they are white or nearly so, and are round or slightly oval. They grow mostly along the longer axis, and become distinctly club-shaped, lacking entirely the plumpness of legume nodules. Branching commonly occurs; one nodule divides to form two or three, and later these branches divide, the whole ultimately forming a cluster of considerable size. The structures are perennial, making new growth and sending out new branches each year. In appearance, as well as to the section knife, they are quite woody, a point that further distinguishes them from legume nodules.

The parasitized zone of a *Ceanothus* nodule may be seen in Plate XV, Fig. 1. The section was mounted in iodine solution, as before described, to show the starch. The meristem and central cylinder do not show. Fig. 2 of the same plate shows a cross-section thru a similar nodule. The central cylinder is well developed and possesses a well defined endodermis. In the nodule cortex surrounding the endodermis, there are first several layers of small, apparently vacant cells, and then a zone of parasitized cells, which are rather loosely scattered in this area. The accumulation of starch in the cells surrounding the parasitized zone shows clearly. As in the legume nodule, there is no epidermis and no root-cap, but there is a protective layer of corky cells.

Plate XVI shows some of the parasitized cells. Fig. 1 is magnified 430 diameters, and Figs. 2 and 3, 1,080 diameters. The dark bodies are said by Arzberger to be sporangia of a fungus, the hyphae of which may be seen within the cells at certain stages. He designates the fungus as *Frankia ceanothi* Atkinson. While not agreeing with Arzberger in all the details, the writers accept the fungous conceptions as the true ones. The parasitized cells are tough and horny in consistency. When nodules were crushed for plating, these cells remained intact and were frequently seen distributed thruout the agar plates, where they were at first mistaken for colonies. No growth was produced by them, however. These parasitized cells clearly bore no resemblance to the bacteroidal cells of the legumes.

Summarizing, the nodules of *Ceanothus* are unlike those of the *Leguminosae* in the following points:

1. The *Ceanothus* nodules differ in external appearance from legume nodules; also, they are quite woody.
2. They are perennial structures, making new growth and producing new branches each year. The mode of branching is different from that of legume nodules.
3. They contain a well developed central cylinder, resembling in this respect a lateral root, of which they may be considered as a modification.
4. The parasitized cells are not closely packed as in the case of legume nodules, the characteristic bacteroids of legume nodules are not present, and the cells do not develop a central vacuole as do bacteroidal cells. Instead, the parasitized cells bear every indication of containing fungous hyphae.
5. No infection threads were found in the nodules of *Ceanothus*.

CYCAS REVOLUTA

Attempts to Isolate the Causal Organism.—Repeated attempts were made to isolate the causal organism from nodules of *Cycas revoluta* obtained from a greenhouse plant. The results were not wholly without success. The nodules of *Cycas* differ from those of the other five groups of non-legumes producing nodules in that the older ones become infected with a blue-green alga,[a] undoubtedly a secondary infection, which renders the nodule less solid and compact. In a cross-section cut from one of these older nodules the algal zone can easily be seen with the unaided eye.

From several algal-infected nodules three forms of bacteria were isolated, none of which resembled *Ps. radicicola.* Two were small, deeply staining rods, and the third was a larger rod. These three organisms were tried in sand pot cultures upon *Pisum arvense, Vicia villosa, Trifolium pratense, Medicago sativa, Melilotus alba, Phaseolus*

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[a] See Spratt [80] [85]; also Life.[67]

vulgaris, Vigna sinensis, Glycine hispida, Lupinus perennis, Arachis hypogoea, Trigonella foenum-graecum, Desmodium canescens, Amphicarpa monoica, Ornithopus sativus, and *Onobrychis sativa.* Only one plant produced nodules—*Trigonella,* on which three appeared. This fact, however, is not regarded as significant, since *Melilotus* and *Medicago* were without nodules. (The nodules of *Trigonella, Melilotus,* and *Medicago,* it has been shown, are produced by the same organism.) Nodules due to chance inoculation are to be expected when open pots are used. It was further observed that the roots of most of the plants were distinctly brown and unhealthy, as tho attacked by a brown rot. The roots of *Pisum, Vicia, Phaseolus,* and *Lupinus* seemed especially to be injured. A small piece of an unhealthy lupine root was teased apart and examined, disclosing a host of motile bacteria.

Young *Cycas* nodules in which the algal zone was not present were plated, but without success. This seemed to indicate that the organisms first isolated were not causal agents, but that they followed the alga. Examination of the algal infected nodules disclosed a very loose, open structure; indeed, the whole nodule lacks the compactness of a *Ceanothus* nodule. The chance for entrance by the alga and later by foreign bacteria is very great. It would be surprising indeed if bacteria were not found in these older nodules.

ALNUS, ELAEAGNUS, AND MYRICA

Spratt,[52] after pointing to the demonstration by Hiltner[45] of the fixation of nitrogen by *Alnus* and *Elaeagnus,* reported the isolation of *Ps. radicicola* from the nodules of these plants. The results reported in connection with the experiments are subject to the following criticisms:

First: The demonstration by Hiltner of the fixation of nitrogen by *Alnus* and *Elaeagnus* is not nearly so convincing as Hellreigel's and Wilfarth's[10] discovery of the symbiosis between *Ps. radicicola* and legumes.

Second: Spratt's method of isolation is at fault. Spratt sterilized nodules and dropped them into flasks containing a liquid medium, incubating them two days. Obviously a single foreign organism in two days becomes a multitude, and no doubt a pure culture. It is not clear whether her agar plates were made from fresh nodule infusions or incubated material as described above, tho it appears that the latter was the case. The method is unsafe unless carried out on a very extensive scale (and then it is questionable), but Spratt used but one culture flask for *Alnus* and one for *Elaeagnus,* leaving one check, which may as well have been omitted. (Agar plates poured from legume nodules as before described, seldom fail to give good plates in this laboratory. If *Ps. radicicola* is present in *Alnus* and *Elaeagnus,* this method should easily demonstrate it.)

Third: The Kiskalt amyl-gram stain described by Harrison and Barlow and used by Spratt does not identify *Ps. radicicola.* Numerous gram-negative soil organisms lose the stain (aniline-gentian-violet) in ethyl alcohol, but retain it when amyl alcohol is used.

Fourth: The coccoid form described by Spratt is not analogous to the bacteroids of *Ps. radicicola.* There is no evidence to show that *Ps. radicicola* ever assumes the shape or characteristics described by Spratt. The writers have never observed it. The only form of *Ps. radicicola* approaching a coccus form is the extremely small, oval *schwärmer* of Beyerinck. The form described by Spratt is entirely too large for the *schwärmer.*

Fifth: The fixation of nitrogen in culture solutions is neither a test for *Ps. radicicola* nor a proof of symbiosis. With the legume organism, the fixation of nitrogen in culture solutions is not significant when compared with fixation in the nodule. Besides, many soil organisms have been attributed this power of fixation in nutrient solutions.

Attempts to Isolate the Causal Organism.—Nodules from *Alnus glutinosa* and *Myrica gale* were obtained and plated out. The results were negative. However, the trials were not extensive because the available material was limited. Ash agar, Spratt's agar, and beef-broth agar were used as media.

CONCLUSIONS

From the foregoing discussion, the following conclusions are drawn:

1. The root-nodules of *Ceanothus, Cycas, Alnus,* and *Myrica* are not caused by *Ps. radicicola.*
2. It is conceivable that *Ps. radicicola* might enter the nodules of *Cycas* as a secondary infection and function symbiotically, but its presence was not demonstrated.
3. The evidence that *Elaeagnus* and *Podocarpus* nodules are caused by *Ps. radicicola* is not conclusive.
4. Proof that these six groups of plants are concerned with the fixation of atmospheric nitrogen is wanting.

Part V.—ATTEMPTS TO DEVELOP A SYMBIOSIS BETWEEN LEGUME BACTERIA AND NON-LEGUME PLANTS

Previous Attempts.—In 1893, Schneider,[18] at the Illinois Experiment Station, under the direction of the senior author, cultivated nodule bacteria from *Phaseolus vulgaris* upon bean-extract agar, then upon a mixture of bean-extract and corn-extract agar, and finally upon pure corn-root-extract agar. Transfers were made every sixth day. After the cultures had grown for a month upon the pure corn-root extract, they were applied upon germinating seeds of corn and oats. Tho the inoculated corn plants produced no nodules, Schneider claimed that they were more thrifty than the uninoculated plants. He described and figured the infection of some of the root-hair cells, as well as some of the epidermal and parenchymal cells. No effect was noted upon oats.

That the senior author was intensely interested in this problem of developing a symbiosis between legume bacteria and non-legume plants is shown by the fact that when the opportunity presented itself after over twenty years, he took up the problem where Schneider[a] had left it.

Other attempts in this direction have been reported. Stutzer, Burri, and Maul[19] inoculated mustard plants with nodule bacteria which had gradually become accustomed to a mustard-plant medium, but without success. Grosbüsch[31] experimented with *Graminae*, but his results were negative.

Lemmermann[27] studied the difference in nutrition between the *Leguminosae* and the *Graminae*. He believed that the reasons for the existence of bacterial symbiosis in the *Leguminosae* and not in the *Graminae* are, namely, the smaller transpiration current, the higher acidity of the root sap, and the greater root development of the former as compared with the latter.

Preliminary Discussion.—How long ago symbiosis between the *Leguminosae* and the nodule bacteria began cannot be estimated. The conditions under which the first infection took place are but a matter of conjecture. Only a mass of contradictory literature concerning this symbiosis existed as a basis in attempting to develop a symbiosis between these bacteria and non-legume plants. There seemed, however, to be several points of attack which offered possibilities. There was some hope that the organism might be modified or changed. By accustoming it to media containing juices of non-legume plants, it was thought that it might become so modified that it would infect such plants. Injury to the plant, especially nitrogen starvation, was a possibility. Mechanical injury, however, seemed useless, since if it would develop a symbiosis the cultivation of crops would long since have accomplished it. The non-legume plants bearing nodules, such as *Ceanothus, Elaeagnus,* and *Cycas,* offered another possibility. It was hoped that if *Ps. radicicola* was present in the nodules, the organism would be more adaptable to other non-legume plants. In addition, the fact that the symbiosis appeared not to be confined to the *Leguminosae* alone was a great encouragement. It became evident, however, on investigating nodules of non-legumes that *Ps. radicicola* was not the causal organism; and furthermore, it seemed very doubtful if these plants were concerned with fixation of atmospheric nitrogen.

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[a] The following excerpts are quoted from a footnote by the senior author introducing Schneider's work in 1893.

"Can the organisms be made to grow upon these roots (grasses or cereals) by artificial means?

"It must be confessed that it would have been exceedingly hazardous for any one to have expressed an affirmative opinion upon this question; but the vast importance of the matter made it desirable to try anything which gave the least promise of success. . . . . While little direct evidence has been gained in favor of ultimate success, it is desirable to publish an account of the work so far done, with the hope of being able at some future time to add greatly to the information now obtained."

Another plan was to obtain a non-legume plant standing in close botanical relationship to the legumes, and attempt to inoculate it with legume bacteria. The organism from cowpea nodules offered the greatest possibilities, since it seemed less particular in its selection of a host plant.

EVIDENCE OF CONSTANCY OR CHANGE IN THE ORGANISM

Moore,[28] in 1905, reported that by inoculating legumes with nodule bacteria from *Pisum sativum* which had been grown for two weeks upon nitrogen-free media, he was able to produce nodules upon many genera. He stated that this was but a single demonstration of numerous successful cross-inoculations. It appears from his work that it was necessary only to grow the organisms upon nitrogen-free media in order to break the special adaptations.

Nobbe and Hiltner,[24] in 1900, claimed that they were able to make the nodule bacteria from peas produce nodules upon the roots of beans, and vice versa.

Laurent,[14] Mazé,[21] and Kellerman, [37] among others, have reported similar successful cross-inoculations.

EXPERIMENT I: COMPARISON OF NITROGEN AND NITROGEN-FREE MEDIA FOR THE GROWTH OF PS. RADICICOLA

In order to compare nitrogen and nitrogen-free media for the growth of *Ps. radicicola,* bacteria from *Melilotus alba* and *Trifolium pratense* were transferred to Freudenreich flasks containing standard beef-broth agar (No. 205) and Fred's synthetic agar (No. 201). The cultures were kept in the incubator at room temperature for thirty months without transfer. Duplicate cultures were transferred to test-tube slants once a month. At the end of the thirty months all cultures were transferred to ash-agar slants for comparison. All were alive and *capable of producing nodules* upon plants in test-tube cultures after Garman's method. Furthermore, it is important to note that the *cultures retained* their *special adaptation* to the *original host* plant and their cultural individualities as described on pages 136 and 139.

EXPERIMENT II: COMPARISON OF ASH AGAR AND BEEF-BROTH AGAR FOR THE GROWTH OF PS. RADICICOLA

Ash agar and beef-broth agar were compared as in Experiment I. Cultures of *Trifolium pratense, Melilotus alba, Vigna sinensis, Glycine hispida, Robinia pseudo-acacia,* and *Arachis hypogoea* were transferred to Freudenreich flasks containing ash agar and beef-broth agar. Duplicate test-tube cultures transferred once a month were kept. The culture of *Robinia pseudo-acacia* upon beef-broth agar was lost because of a mold. After seventeen months the cultures were transferred to ash-agar slants for comparison. All were alive (except the *Robinia*) and all *retained their individual habit of growth. Trifolium pratense* and *Melilotus alba* were tested by Garman's method and the others in sand pot cultures. (The remaining *Robinia* cultures were not tested except for growth.) All those tested were *capable of producing nodules* upon their *original hosts.* A few cross-inoculations were tried but failed. No difference in virulence was noted.

EXPERIMENT III: GROWTH OF PS. RADICICOLA ON TOMATO-STEM SLANTS

For the purpose of infecting tomato plants, cultures of *Melilotus alba* and *Trifolium pratense* were grown upon tomato-stem slants (No. 421) placed in tubes containing standard beef broth. Transfers were made once a month. After several months, distilled water was substituted for the broth. At the end of twenty-three months the cultures were transferred to ash-agar slants. Eight cultures of *Melilotus alba* and two of *Trifolium pratense* were examined. All grew readily when transferred to ash-agar slants. Tested in agar-tube cultures, all *produced nodules* upon their *original hosts. Melilotus alba* bacteria, however, failed to inoculate *Trifolium pratense* plants, and *Trifolium* bacteria failed with *Melilotus* seedlings.

EXPERIMENT IV: COMPARISON OF ASH AGAR AND CONN'S ASPARAGINATE AGAR AND THE EFFECT OF SUNLIGHT ON GROWTH AND VIRULENCE OF PS. RADICICOLA

This experiment was designed not only to compare nitrogenous and non-nitrogenous media, but also to note the effect upon growth and virulence of exposure to direct sunlight. Cultures of organisms from various legumes were transferred to Freudenreich flasks of 25-cc.

capacity, two sets containing Conn's asparaginate agar and two ash agar. All cultures were incubated for three days at room temperature, after which one set of the asparaginate-agar flasks and one of the ash-agar were removed to the greenhouse and left exposed to the sunlight. The slopes were turned toward the south to give maximum exposure. The checks, fewer in number, were left in the incubator. The experiment covered three months—from March 2 to June 2, 1916. The temperature in the greenhouse varied from 18° to 42.5° C.[a] The highest temperature recorded within a similarly prepared flask was 47° C. (thermometer shaded). In Table 11 is shown the arrangement of the experiment.

TABLE 11.—ARRANGEMENT OF CULTURES TESTED ON ASH AGAR AND CONN'S ASPARAGINATE AGAR IN SUNLIGHT AND IN DARKNESS: EXPERIMENT IV

Source of organism		In sunlight		In darkness	
Common name	Botanical name	Ash agar	Conn's agar	Ash agar	Conn's agar
		Flask No.	*Flask No.*	*Flask No.*	*Flask No.*
Acacia	*Acacia melanoxylon*	6011 (died)	6026	....	....
Tick trefoil	*Desmodium canescens*	6012	6027	....	....
Dyer's greenweed	*Genista tinctoria*	6013	6028	....	....
Soybean	*Glycine hispida*	6014	6029	....	....
Sweet pea	*Lathyrus odoratus*	6015	6030	6016	6031
White sweet clover	*Melilotus alba*	6017 (lost)	6032	6018	6033
Bean	*Phaseolus vulgaris*	6019	6034	....	....
Trailing wild bean	*Strophostyles helvola*	6020	6035	....	....
Red clover	*Trifolium pratense*	6021	6036	6022	6037
Broad bean	*Vicia faba*	6023	6038	....	....
Cowpea	*Vigna sinensis*	6024 (died)	6039 (died)	6025	6040

At the end of three months all cultures were transferred to ash-agar slants. Flask No. 6017 had been broken; the cultures in Nos. 6011, 6024, and 6039 had died. Of the surviving cultures those which had been kept in darkness recovered the most quickly. It was also noted that the organisms grown upon Conn's asparaginate agar were the most vigorous. The ash-agar cultures which had been exposed to sunlight were the slowest in recovery. After several transfers upon ash agar, the cultures resumed their normal appearance. They were then tested out for virulence (except *Phaseolus* and *Strophostyles*), and it was found that the *ability to produce nodules had not been affected.* The cultures of *Melilotus* and *Trifolium* were tested by Garman's method for ability to cross-inoculate seedlings of *Trifolium* and *Melilotus* respectively, but the cultures were virulent *only* upon the *original* host.

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[a] The spring was cool and cloudy for the most part, tho there were some clear, hot days.

EXPERIMENTS ATTEMPTING THE INFECTION OF NON-LEGUME PLANTS WITH PS. RADICICOLA

The following experiments attempting the infection of non-legume plants with *Ps. radicicola* were but preliminary. In examining inoculated plants, attention was given only to any unexplained vigor and to the presence or absence of abnormal root conditions. Histological technic was not employed.

EXPERIMENT V: ATTEMPTED INFECTION OF TOMATO SEEDLINGS WITH SWEET-CLOVER BACTERIA

Very young tomato seedlings were transferred from flats of soil to one-gallon pots of limed white quartz sand. There were in all one hundred and fifty plants. Half were given a full nutrient solution,[a] and half were given a similar solution but without the nitrogen. Copious inoculations were made frequently with bacteria from sweet clover which had been grown for three weeks, with frequent transfers, upon a decoction of whole tomato plants plus two percent cane sugar and one percent peptone (Medium No. 111). After one month the plants were carefully washed free from sand and examined. Those which had been receiving nitrogen were decidedly more thrifty than the others. No abnormal conditions were observed in the roots.

EXPERIMENT VI: ATTEMPTED INFECTION OF TOMATO SEEDLINGS WITH SWEET-CLOVER BACTERIA IN THE PRESENCE OF COPPER SULFATE

Tomato seedlings which had been grown in flats of soil were transferred to paper boxes containing limed white quartz sand, one plant to each box. These boxes (2" x 2" x 4¾") were arranged in a wooden frame, sixteen rows of sixteen each, making two hundred and fifty-six in all. Nutrient solutions made up as before were used, except that the nitrogen was varied as indicated in Table 12. Inoculations were made at the time of transplanting and again after two weeks with

TABLE 12.—TREATMENT APPLIED TO TOMATO SEEDLINGS: EXPERIMENT VI

Section No.	No. of plants	Nitrogen treatment	Copper-sulfate treatment
738	32	Full nutrient solution[a] (10 cc. stock solution per liter water)	None
739	32	Full nutrient solution	50 cc. of 1:2500 solution
740	32	Full nutrient solution	50 cc. of 1:1000 solution
741	32	Full nutrient solution	50 cc. of 1:500 solution
742	32	Nutrient solution without nitrogen	None
743	32	Double nutrient solution	None
744	32	Nutrient solution without nitrogen	50 cc. of 1:1000 solution
745	32	Double nutrient solution	50 cc. of 1:1000 solution

[a] See footnote, page 125.

bacteria from sweet clover which had grown upon tomato-infusion peptone (No. 111). After ten days copper sulfate was applied to the sections indicated in amounts intended to stimulate growth, to just hinder growth, and to seriously retard growth. The treatment is shown in Table 12.

The plants were examined after four weeks. Those which had received the normal amount of nitrogen showed the best development. The 1:2500 solution of copper sulfate stimulated both root and top development; the 1:1000 solution was slightly injurious; and the 1:500 damaged the plants seriously. No abnormal conditions of the roots were observed, except where the 1:500 copper-sulfate solution was applied, in which cases the injury was apparent.

EXPERIMENT VII: ATTEMPTED INFECTION OF TOMATO SEEDLINGS WITH SWEET-CLOVER BACTERIA IN SOIL AND IN SAND WITH VARIED NITROGEN TREATMENT

Tomato seedlings growing in sand and in soil in an arrangement similar to that of Experiment VI were inoculated with bacteria from sweet clover which had been grown for ten months upon tomato-stem slants (No. 421). Bacteria were applied at the beginning of the experiment and at intervals of a week thereafter. The nitrogen treatments used were varied as shown in Table 13.

TABLE 13.—TREATMENT APPLIED TO TOMATO SEEDLINGS IN SOIL AND IN SAND: EXPERIMENT VII

Section	Sand or soil	No. of plants	Treatment	Remarks
A	Sand	256	Full nutrient solution	
B	Sand	256	Nutrient solution without nitrogen	A small amount of nitrogen was added later, as the plants were starving. With the exception of a few very weak plants, however, all died
C	Sand	224	Harrison-Barlow wood-ash (No. 100)	
D	Soil	288	Tap water	Plants grew very vigorously and were cut back. 160 plants were given 1:500 copper sulfate solution to further check the growth
E	Sand	128	Nutrient solution with 1/10 nitrogen	
F	Sand	112	Nutrient solution with nitrogen trebled	
G	Soil	112	Tap water	Plants were cut back
H	Soil	112	Nutrient solution with nitrogen trebled	Plants were cut back

In general it may be said that the plants in soil were the most vigorous. Those in sand without nitrogen made very weak growth or died. Those watered with ash solution also made very little growth, probably because of a lack of nitrogen. The roots of the plants bore no abnormal structures.

EXPERIMENT VIII: ATTEMPTED INFECTION OF COMMON MORNING GLORY WITH SWEET-CLOVER BACTERIA

The plan was much like that of Experiment VII, except that common morning glory (*Convolvulus major*) was used. Seeds were planted in sand and in soil, using the paper boxes before described. There were 1,556 plants in all. Inoculations were made at the time of planting and again in two weeks with nodule bacteria of sweet clover which had been grown for one month, with frequent transfers, in an infusion of morning-glory plants plus two percent cane sugar and one percent peptone. Unfortunately some of the records were lost, but Plate XVII gives a general idea of the experiment. The inoculation produced no visible effect. The roots were carefully examined but showed no unusual conditions.

EXPERIMENT IX: ATTEMPTED INFECTION OF TOMATO SEEDLINGS WITH SWEET-CLOVER BACTERIA AND WITH A COMPOSITE INFUSION OF MANY LEGUME BACTERIA

The experiment involved 1,268 tomato seedlings grown in paper boxes filled with limed white quartz sand. These were divided into two equal sections. Those in one section were given the full nutrient solution, while those in the other were given the nutrient solution without nitrogen. Half the plants in each section were inoculated with sweet-clover bacteria which had been grown for twelve months upon tomato-stem slants (No. 421). The other half were inoculated with a composite of all the cultures of nodule bacteria on hand. There were cultures from forty-five plant species, including twenty different generic groups. Some were recent isolations, but most of them had been kept as stock cultures for one to two years. All had been grown upon ash-agar slants. The inoculations were in every case without apparent effect.

EXPERIMENT X: ATTEMPTED INFECTION OF STRAWBERRY PLANTS WITH SWEET-CLOVER BACTERIA AND WITH A COMPOSITE INFUSION OF BACTERIA FROM SEVEN SPECIES OF ACACIA

Young strawberry plants, one hundred and twenty in all, were planted in one-gallon pots of sand and of soil and treated as shown in Table 14. Half the plants in each series were inoculated with sweet-

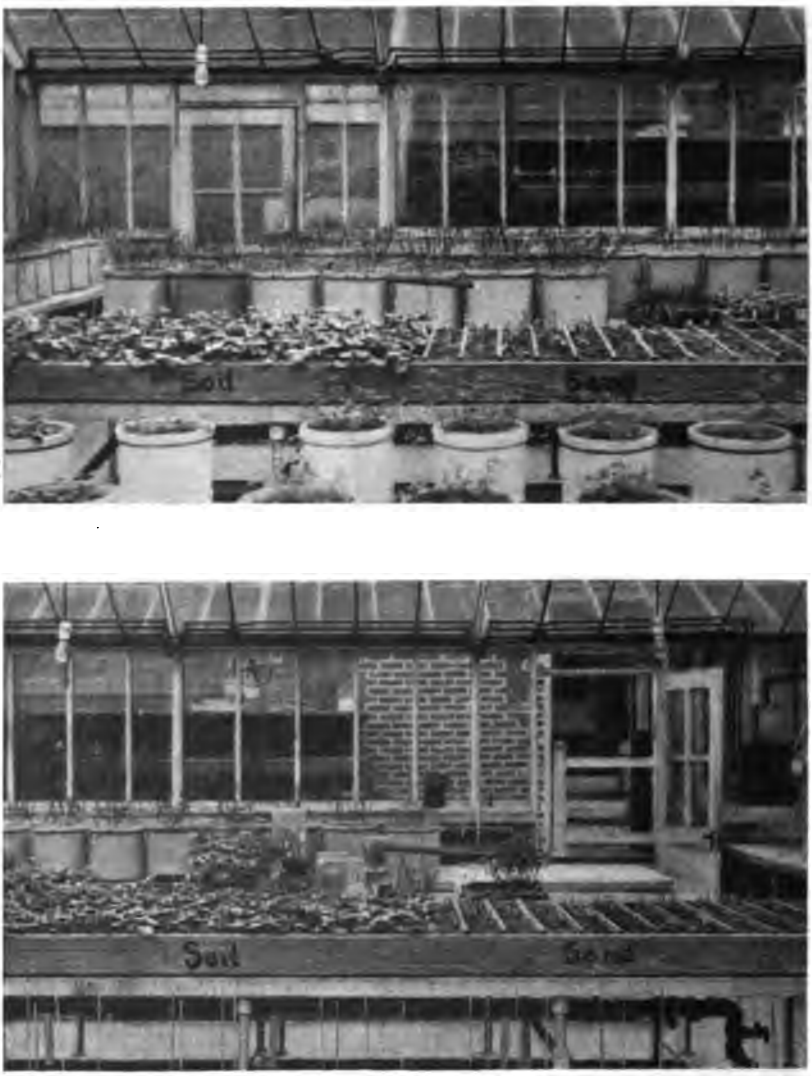

PLATE XVII

Experiment VIII: Morning-glory plants grown in sand and in soil inoculated with sweet-clover bacteria grown for one month in morning-glory infusion media

TABLE 14.—TREATMENT APPLIED TO STRAWBERRY PLANTS IN SAND AND IN SOIL: EXPERIMENT X

Series	No. of plants	Medium	Treatment
A	30	Good potting soil	Tap water only
B	30	1 part soil to 4 parts sand	Tap water only
C	30	Washed yellow sand	Full nutrient solution
D	30	Washed yellow sand	Full nutrient solution without nitrogen

clover bacteria; the other half were inoculated with a composite infusion of bacteria from seven species of *Acacia.* Heavy inoculations were made frequently; the bacteria used had been grown upon ash-agar slants.

The plants did well at first, but later became infested with red spiders and in spite of sprays did not make a satisfactory growth. The results were negative.

SUMMARY

1. The nodule bacteria studied were found to be true *Schizomycetes,* actively motile by means of a single polar flagellum.

2. These bacteria may be divided into groups according to the host plants to which they become specifically adapted. In addition to the cross-inoculations previously known, many new ones were found to exist. These are given under Group III, page 136.

3. In addition to these special adaptations, there are among the various nodule bacteria serological and cultural differences which are permanent, giving perhaps a legitimate basis for the belief that distinct species exist. In numerous other characteristics, however, the nodule bacteria are so strikingly alike, and as a whole they differ so widely from any other species of bacteria, that it seems more consistent to regard the adapted forms as varieties of the single species *Pseudomonas radicicola.*

4. The legume nodule originates in the root-cortex, much as does the lateral root, but here the similarity ends. The nodule consists chiefly of a mass of parenchymal cells which are devastated by the nodule bacteria giving way to the bacteroid forms of the invading organism, which then make up the greater part of the cell contents.

5. The nodules of the non-legumes *Ceanothus, Cycas, Alnus,* and *Myrica,* said to be concerned with the fixation of atmospheric nitrogen, are not caused by *Pseudomonas radicicola.* The nodules of *Ceanothus* are wholly different morphologically from those of the *Leguminosae.* The evidence that the nodules of *Elaeagnus* and *Podocarpus* are caused by these organisms is not conclusive. Furthermore, the proof that any of these six groups of plants are concerned in the fixation of atmospheric nitrogen is not conclusive.

6. The adaptations of the nodule bacteria are constant. Such factors as the use of organic or inorganic substances in the medium, the acidity or alkalinity of the medium, and the presence or absence of combined nitrogen in the same, do not affect the virulence nor break the special adaptations. The virulence and specificity are bound up with the life of the organism.

7. The preliminary experiments here reported attempting the infection of non-legume plants with nodule bacteria failed.

8. No conclusions can be drawn as to the possibility or probability of developing or finding nodule bacteria that will grow on non-legume plants. The constancy of the special adaptations and the fact that no plants other than legumes harbor the organisms in question, as had been supposed, have been discouraging and to some degree limit the hope of ultimate success.

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[1] In the preparation of these bibliographies assistance was also rendered by Albert L. Whiting, Associate in Soil Biology, Warren R. Schoonover, First Assistant in Soil Biology, and William A. Albrecht, Fellow in Agronomy.

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UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

BULLETIN No. 203

SEED PRODUCTION IN APPLES

By CHARLES S. CRANDALL

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SUMMARY OF BULLETIN NO. 203

1. In this bulletin is recorded the seed production of four groups of apples, a total of 31,972 fruits: large apples of orchard varieties, 12,912; small apples of orchard varieties, 8,500; crabs, 6,642; and hand-pollinated fruits, 3.918.

2. Seed production in large apples exceeded that in small apples by 14.7 percent, and was nearly twice that recorded for crab fruits; the average seed production was, for large apples, 8.27; for small apples, 7.21; and. for crab fruits, 4.22. **Page 188**

3. The minimum average seed content was 2.8, found in small fruits of Collins; the maximum average was 15.04, found in large fruits of Shockley. **Page 188**

4. Approximately 12 percent of the large fruits of orchard varieties contained the assumed normal of 10 seeds; 69 percent averaged below this normal, and about 18 percent above normal. **Page 189**

5. There was considerable variation in number of carpels; four orchard varieties held to the normal of five; all others showed departures from this normal. The range for large fruits was 4 to 8; for small fruits, 2 to 8. **Page 191**

6. Parthenocarpic fruits were found more often among small fruits than among large fruits of orchard varieties. **Page 190**

7. Percentages of ovules that developed as seeds were higher for groups of large apples than for small apples in twenty out of twenty-one varieties examined. **Page 198**

8. A test of extremes in size for one variety confirmed results from all varieties and strengthened the evidence that large apples develop a larger proportion of the ovules they contain than do small apples. **Page 199**

9. Crab fruits ranged in numbers of carpels from 2 to 12 and had a seed range of 0 to 14. **Pages 205, 207**

10. Production of ovules in excess of the expected normal occurred more frequently among orchard varieties than among crabs. **Page 211**

11. Control of pollination exercised no marked influence on numbers of seeds developed. **Page 213**

SEED PRODUCTION IN APPLES

By CHARLES S. CRANDALL, Chief in Plant Breeding in Horticulture

INTRODUCTION

Each normal fruit of the common apple is made up of five centrally located carpels, each carpel forming one cell. Each of the five cells contains two ovules attached near the base to the perpendicular placenta, which is on the inner side of the cell, and hence central in the fruit. When all ovules are fertilized and develop into seeds, the full complement is ten for each normal apple.

Examination of a considerable number of apples brings out the fact that departures from the normal number of seeds are common and of all degrees, from an entire absence of developed seeds to an increase to more than two and one-half times the normal. Naturally these variations in the performance of individuals and varieties in the matter of seed production suggest questions regarding the factors governing fertilization and seed development, the relation of seed formation to size of fruit, and the possibility of developing a definite system of association of orchard varieties that would make for increase in fruit production. The development of such a system could not be accomplished in one year, nor in several years; it would require long and patient effort, but there can be no doubt that valuable scientific as well as economic results would attend its successful accomplishment. It is not the intention to enlarge upon this idea in the present publication, but simply to place on record observations that have been made relative to the actual seed production of groups of apple varieties grown under usual orchard conditions.

As a first step in a study of seed production in apples it is desirable to know something of the behavior of common orchard varieties in this regard. Do they live up to the possibilities in the matter of seed production? Do they fall short of, or do they exceed a definite normal? Are there well-defined differences in seed production that may rank as varietal characteristics? How do varieties producing very large fruits, Wolf River for example, compare in seed production with varieties producing small fruits, such as Red June or Lady? Within a variety, does any definite relation exist between size of fruit and seed content? These are some of the questions that are suggested at the outset of the inquiry.

OPINIONS REGARDING SEED PRODUCTION

Horticultural literature, so far as consulted, yields little information concerning the questions here suggested. Seed production in apples appears to have been passed over. There are no records of extended investigation and only meager references to the performance of this fruit in this particular. There do appear certain statements indicating common belief in a general principle that with seed-bearing plants, and especially with economic fruit plants, in which there is large development of edible parts, there is a corresponding diminution in seed-producing capacity; or, to state it more definitely, fruits with highly developed fleshy parts produce fewer seeds than do those fruits in which the fleshy parts are not enlarged.

The development of seeds, the forming of the embryos, and the storing of food necessary for the young plants form an exhaustive process drawing heavily upon the resources of the plant. It is a perfectly natural conclusion that the production of full complements of seeds and the storing of large quantities of edible fruit flesh are antagonistic and that large size and full seed production are not likely to be at a maximum in the same fruits.

In discussing compensation and economy of growth, Darwin[1] makes this general statement:

> "When the seeds in our fruits become atrophied, the fruit itself gains largely in size and quality."

Lindley says[2]:

> "Sterility is a common malady of cultivated plants, the finer varieties of fruit, and all double and highly cultivated flowers, being more frequently barren than fertile. This arises from several causes. The most common cause of sterility is an unnatural development of some organ in the vicinity of the seed, which attracts to itself the organizable matter that would otherwise be applicable to the support of the seed. Of this the Pear, the Pineapple, and the Plantain are illustrative instances."

E. L. Sturtevant[3] affirms that small fruits contain more developed seeds than do large fruits. He writes as follows:

> "The better varieties of the apple usually contain some abortive seeds and are sometimes individually to be found seedless. As a rule, where there is a tendency to abortive seeds, the larger and finer the apple the greater the number of abortive seeds. Thus five Baldwin apples, weighing thirty ounces, had eleven plump and nine shriveled seeds; five others from the same barrel, and weighing seventeen ounces, furnished twenty-five plump and three abortive seeds."

Dr. Sturtevant's conclusion appears to be based upon examination of 145 apples representing thirty-five varieties. One variety, the Baldwin, was represented by sixty-seven apples; of the others, eighteen had one fruit each, four had two each, and twelve had numbers of fruits from three to eight. The average number of good seeds was 5.67; the minimum number found was one each in Newtown Pippin and Gray Russet; the maximum was 12.75 in Northern Spy. The numbers of fruits examined, however, were too small, at least for all varieties except Baldwin, to serve as a good index of the seed-producing capacities of the varieties.

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[1] Origin of Species, 6th ed., p. 139.

[2] Theory of Horticulture, Downing, 2d. ed. (1852), p. 170.

[3] On Seedless Fruits, Mem. Torrey Bot. Club, 1, No. 4 (1890), p. 145.

The authors quoted do not state the converse of the principle laid down, but each leaves the reader to infer that fruits not highly developed, those in or near the wild state, while deficient in flesh, the part valuable to man, excel in seed production.

Bailey[1] expresses a view contrary to that given by the writers quoted above. He says:

> "As a rule, the cultivated varieties of apples contain more seeds than the wild apples of Europe do. Forty specimens of the wild crab (*Pyrus Malus*) of central Europe produced an aggregate of two hundred fifty-six seeds, or an average of six and two-fifths seeds to each fruit. Forty Northern Spys contained four hundred eighty-one seeds, or an average of twelve and one-fortieth to the fruit. Normally, the apple should contain ten seeds, two to each carpel, but some of these Spys had fifteen seeds and one had eighteen. Yet some other varieties of apples contain fewer than the normal number, while some are almost entirely seedless. There is generally a slight increase in seed production as fruits develop away from the first type, especially if the fruits become larger. This is a natural consequence of the increase in size, tho it bears no constant ratio to this increase."

SEED-PRODUCTION RECORDS

As a basis from which to judge the performance of apples and crabs in seed production when varieties are grown in mixed plantations and left open for undisturbed visitation by insects, records were taken from 28,054 individual apples. Thirty-two orchard varieties were represented by 21,412 fruits, and twenty-five species and varieties of the genus *Malus* were represented by 6,642 fruits. This latter is a strictly crab group; none of the species or varieties have any economic value other than as ornamentals. They vary widely among themselves and represent several types, but all closely approximate the wild originals.

With the exception of Garfield and Twenty Ounce, varieties represented by small numbers of fruits very uniform in size, the fruits of each orchard variety were divided into two groups on the basis of size, a group of large apples and a group of small apples, in order to determine whether or not there is constant difference in seed production between groups thus separated. Transverse diameter was taken as the basis of division. In a few varieties all fruits 65 mm. or above in diameter were classed as large, all below that dimension as small. In most varieties, however, it was possible to leave a gap of from 3 to 10 mm. between groups and in that way make them more distinct; thus, in several varieties the maximum for the group of small apples was 70 mm., and the minimum for the group of large apples, 75 mm.

In the crab group there prevailed such uniformity in the size of fruit within each species or variety that no division into size-groups was attempted.

Records obtained from the fruits examined support the view that the more highly developed fruits, that is to say, such fruits as are produced by varieties commonly grown in orchards, develop seeds in greater numbers than do the crab-like fruits of less highly developed forms of the genus *Malus*. A further fact developed from the records was that in nearly all the varieties, the fruits of which were divided into size-groups, the groups containing large apples produced more seeds than did the groups containing small apples. The differences between these three classes of fruits in average seed production are as follows:

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[1] The Survival of the Unlike (1901), p. 253.

1. **Average seeds to the fruit for 12,912 apples of large size, representing thirty-two varieties, 8.27.**
2. **Average seeds to the fruit for 8,500 apples of small size, representing thirty varieties, 7.21.**
3. **Average seeds to the fruit for 6,642 apples, representing twenty-five crab-like forms of *Malus*, 4.22.**

Here the average for large orchard fruits exceeds the average for small orchard fruits by 14.7 percent, and is very nearly twice as great as for the crab-like forms.

In each of the three groups for which average seed production is given there was a wide range between maximum and minimum seed production as exhibited by the different varieties and species. Thus, among the groups of large fruits, Collins was the least productive, the average for 261 fruits being 4.09 seeds, and Shockley the most productive, with an average for 177 fruits of 15.04 seeds. In the groups of small fruits, Collins was again the least productive, with an average for 150 apples of 2.8 seeds: the maximum here, as in the groups of large fruits, falls to Shockley, which, for 177 apples, had an average of 14.59 seeds.

In the crab group the lowest in seed production was *Malus fusca,* with an average of 1.32 seeds to each fruit, but this species was represented by so few fruits that this average is not regarded as dependable for the species. The next lowest was *Malus atrosanguinea,* which, for the 100 fruits examined, had an average of 2.02 seeds to each fruit. The most productive in this group was *Malus Malus flore pleno,* which, for 100 fruits, had an average of 7.8 seeds to each fruit. The second in seed production was *Malus microcarpa,* which, for 100 fruits, had an average of 7.09 seeds to each fruit.

Between the extremes in seed production given for the different classes of fruits the averages were various: no two were alike, but the majority tended towards approximation of the general average for the class. High seed production appeared to be characteristic of some orchard varieties, while certain others of these varieties were equally constant in low production. Some varieties tended to concentrate within the normal of ten seeds, as was the case with Arkansas Black, Grimes, Fameuse, and Rome; others tended to scatter the production over a wide range, as 1 to 27 in Shockley, 3 to 21 in Rhenish May, and 3 to 19 in Winter Rambo. In the groups of apples

TABLE 1.-

Variety	No. of fruits	Average wt. in grams	Aver. diam. (mm.)		Distribution of fruits as to cells				
			Long	Transverse	4	5	6	7	8
Arkansas Black	225	165.54	60.23	71.15	1	224			
Bailey Sweet	200	151.10	63.67	74.16		199	1		
Ben Davis	1 393	144.26	58.84	70.99		1 392	1		
Collins	261	175.20	57.90	74.00	2	259			
Crawford	200	57.83	41.72	48.66	11	189			
Fameuse	200	115.66	55.13	66.33		200			
Garfield	100	178.59	68.22	74.04	4	96			
Golden Ball	200	200.14	65.41	80.64		198	2		
Grimes	293	130.69	57.01	67.02		292	1		
Hibernal	200	121.05	52.85	70.88		200			
Huntsman	731	120.76	50.32	67.56		649	80	2	
Indian	200	112.26	55.96	64.59		200			
Isham	200	141.18	60.39	69.06		200			
Jonathan	374	141.46	60.31	70.91		374			
Mammoth Black Twig	200	151.95	57.88	71.61		199	1		
McClellan	200	128.00	55.86	69.25	1	199			
McMahon	200	154.93	58.93	75.49	3	196	1		
Minkler	863	170.85	57.29	73.31	2	837	21	2	1
Osceola	200	105.17	51.23	63.64		199	1		
Polische Jungfrau	200	116.80	51.52	67.54		198	2		
Rhenish May	2 398	107.10	50.80	63.01	5	2 276	117		
Rome	200	126.72	52.41	64.42		198	2		
Shockley	177	234.76	68.64	82.93		177			
Smith Cider	328	125.58	53.83	66.40		324	4		
Tolman	200	121.16	59.04	69.00		196	4		
Twenty Ounce	166	197.31	67.90	78.90		165	1		
Wealthy	513	132.10	57.25	70.73		512	1		
Willow	150	119.06	54.10	65.70		117	29	3	1
Winesap	1 190	106.09	50.77	61.42	2	1 185	3		
Winter Rambo	550	135.51	54.20	68.72	1	391	119	35	4
Wolf River	200	207.94	64.37	84.51		199	1		
Wythe	200	113.96	51.19	67.81	1	198	1		
Total	12 912								

ber of se	
15	16
1	
3	
11	
21	

ber of seeds per fruit												
15	16	17	18	19	20	21	22	23	24	25	26	27
1												
3	1	1										
11	3	3	3									
21	16	16	13	11	14	9	1	2				1
1												
4	1	1										
2	3											
	2											

of large size, no fruits had less than four seeds in Garfield, Osceola, Polische Jungfrau, and Wythe; none had less than three in Crawford, Rhenish May, Smith Cider, Willow, Winesap, and Winter Rambo.

Seedless apples occurred in the large size-groups of McMahon and Twenty Ounce, in both size-groups of Ben Davis, Collins, Golden Ball, Minkler, and Wealthy, and in the small size-groups of Bailey Sweet, Indian, Jonathan, Isham, Osceola, Rhenish May, Shockley, Tolman, and Winesap; they occurred rather more frequently among small apples than among large. Seedless apples will be referred to again in connection with detailed accounts of the several classes of fruits.

ORCHARD VARIETIES

Records of numbers of carpels and distribution of seeds for the two size-groups of orchard varieties are brought together in tabular form in Tables 1 and 2. Records of ovule production of the orchard varieties are presented in Table 7.

Distribution of seed production in its relation to the full normal content of ten seeds is of interest as showing the extent of departures from the normal in both directions. Considering the apples according to the classes into which they have been divided, the apples of large size as produced by orchard varieties may come first.

SEED DISTRIBUTION OF APPLES OF LARGE SIZE

The apples of large size included thirty-two varietal groups, aggregating 12,912 apples; they produced 106,845 seeds, an average of 8.27 seeds to each fruit. The number of apples producing the normal of ten seeds was 1,610, or 12.5 percent of the whole number. These apples bore 16,100 seeds, or approximately 15 percent of the number of seeds produced by all fruits of the group. The number of apples falling below normal in seed production was 8,913, or 69 percent of the total; these apples bore 58,412 seeds, or 54.67 percent of the total produced by fruits of this class. With seed production above normal there remained 2,389 apples, or 18.5 percent of the total; these bore 32,333 seeds, or 30.26 percent of the total seeds.

SEED DISTRIBUTION OF APPLES OF SMALL SIZE

The groups of small apples represented thirty varieties, and together contained 8,500 apples which produced 61,325 seeds, an average of 7.21 to each fruit. The number of apples producing the normal of ten seeds was 1,020, or 12 percent of the total; these produced 10,200 seeds, or 16.63 percent of the total. The number of apples producing less than ten seeds was 6,786, or 79.84 percent of the total; these produced 42,178 seeds, or 68.78 percent of the seeds produced by the group. The number of apples with seeds ranging above ten was 694, or 8.16 percent: these produced 8,947 seeds, or 14.59 percent of the seed total.

COMPARISON OF SEED DISTRIBUTION OF THE TWO SIZE-GROUPS

Comparing the size-groups, it is seen that the percentages of fruits having the normal number of ten seeds were nearly the same, 12.5 percent for the large and 12 percent for the small. In numbers of fruits having seeds in excess of ten the large fruits lead by a considerable margin; the percentages were 18.5 for large and 8.16 for small. Of fruits with less than the normal number of seeds, small fruits had the greatest numbers, nearly 80 percent as compared with 69 percent for large fruits. Seedless fruits numbered 37 among large apples and 64 among small apples. Apples having one seed each numbered 93 for the groups of large apples and 121 for the groups of small apples. With two seeds each there were 231 large apples and 277 small apples; from this there was a gradual increase in number of apples with each addition to the seeds to each fruit, until the maximum of 1,843 apples of large size and 1,257 apples of small size was reached with nine seeds to each fruit. Above this the decline in numbers was rapid for both classes, but there were still a considerable number of apples having large excess in numbers of seeds. Thus, 95 large apples had eighteen seeds each, 48 had nineteen each, and 36 had twenty or above. Among small apples, 16 had eighteen seeds each, 11 had nineteen each, and 27 had twenty or above.

NUMBER AND DISTRIBUTION OF CARPELS

The number of carpels in a normal apple is five, but just as there are more or less frequent abnormalities in number of floral parts, sepals, petals, and stamens, so there are departures from the normal in number of cells in the compound ovary. Among fruits of orchard varieties examined there were found 789 apples, or 3.68 percent of the total number, that departed from the normal in number of cells. Increase in number was much more frequent than diminution; 129 fruits had less than five cells and 660 had more than five.

Distribution of the abnormalities among varieties was not at all uniform. Winter Rambo had more than any other variety, 243 out of 1,050 apples, or 23.14 percent: 1 fruit had four cells, 186 had six cells, 50 had seven cells, and 6 had eight cells, while 807 were normal with five cells each. Rhenish May had the next largest number of fruits showing departures from normal, 219, but because of the larger number of apples examined the percentage was only 6.42, much lower than for Winter Rambo. In this variety there were 8 fruits with three cells each, 50 with four cells, 160 with six cells, and 1 with seven cells. Huntsman had the third largest number of abnormalities, with 130 six-celled fruits and 2 having seven cells each. This variety was represented by 1,261 apples, and the percentage of departures from normal was 10.46. Numbers of fruits with other than normal cells were very much smaller for the remaining twenty-five varieties among which they were distributed. Five of these varieties, Bailey Sweet, Grimes, Osceola, Twenty Ounce, and Wolf River, with an aggregate of 1,911 apples, had each one six-celled fruit, all others being five-celled. Four varieties, Indian, Isham, Jonathan, and Shockley, with a total of 1,606 apples, had only five-celled fruits.

As between the two size-groups, large and small, there was very little difference in the frequency with which abnormalities in cells appeared. In the group of large apples there were 474 fruits having cells above or below the normal number; in the group of small apples the number was 315, but large apples were more numerous than small and the ratio of abnormalities was practically equal for the two groups.

VARIETIES HIGH IN SEED PRODUCTION

Certain of our varieties exhibited an exceptionally strong tendency to multiplication of seeds; at least three of these, Winter Rambo, Rhenish May, and Shockley, are perhaps worthy of individual consideration.

WINTER RAMBO

In the large size-group of Winter Rambo were four apples, each with eight cells containing plump and abortive seeds, as follows: 10-6, 16-3, 11-5, and 12-4. In the second of these fruits there was an addition of three to the expected number of ovules. Irregularity in number of ovules appeared to be characteristic of this variety; the range was from the normal of 10 for a five-celled fruit to 24 for a six-celled fruit. One of the fruits examined had six cells with 4 ovules in each cell, 19 of which developed into seeds. Of 550 Winter Rambo apples of large size, 35, or more than 6 percent, had each seven cells. These apples contained 565 ovules, an average of 16.14. The expected total of ovules in 35 seven-celled apples is 490; hence there was here an excess of over 15 percent. The seeds that developed numbered 411; this represents 72.75 percent of the ovules present, but falls a little more than 16 percent below the full complement for 35 seven-celled fruits. The lowest seed production in these fruits was six in one fruit having 14 ovules; the maximum production was seventeen seeds in a fruit having 17 ovules. The maximum seed production in this variety falls to two six-celled apples, one of which had 19 ovules, all of which formed good, plump seeds; the other had 24 ovules, 19 of which became fully developed seeds. At the other extreme were two fruits with three seeds each, both having the expected number of ovules, one fruit five-celled, the other six-celled.

In this variety there were considerable differences between large fruits and small fruits in number and distribution of seeds. These differences are best shown by a direct comparison of the distribution percentages presented in Table 3.

TABLE 3.—DISTRIBUTION OF SEEDS IN LARGE AND SMALL WINTER RAMBO APPLES

Size-group	Number of apples	Distribution of seeds			Average seed content
		Percentage normal	Percentage below normal	Percentage above normal	
Large........	550	17.09	45.64	37.27	9.98
Small........	500	13.80	72.00	14.20	8.30

NOTE.—Normal is here taken to be ten seeds to each five-celled fruit.

The large fruits exceeded the small fruits by more than 20 percent in average of seeds to each fruit and by more than 32 percent in number of seeds produced. The fruits having seeds in excess of the normal were nearly three times as numerous in the group of large apples as in the group of small apples, while of the apples below normal in seed production the small apples exceeded the large by about 35 percent. In this variety, then, it is evident that the large fruits were greater seed producers than were the small fruits.

RHENISH MAY

The second of the three varieties showing greatest tendency to multiplication of seeds was Rhenish May, in which the large size-group was represented by 2,398 apples and the small size-group by 1,009 apples. For the large apples the average seed production was 11.65 and for the small apples 7.55. Ten percent of the large apples contained ten seeds each and produced 9 percent of the seed total for large apples; 30 percent had numbers of seeds below ten and carried 19 percent of the total number of seeds, while 60 percent of the fruits had seeds in excess of ten and carried 72 percent of the seeds. In the group of small apples the percentage of fruits having the normal of ten seeds each was 10, the same as for the large apples, and they had 13.3 percent of the seeds borne by the group. The percentage of fruits with less than ten seeds was very much greater than for the large fruits, 72.4 percent as against 30 percent for the large fruits, and these carried 58.1 percent of all the seeds. Only 17.6 percent of this group had above ten seeds each, but they produced 28.6 percent of the total number of seeds. The superiority of large apples as compared with small apples in seed production was as well defined in Rhenish May as in Winter Rambo. In Table 4 are presented the figures for seed distribution in Rhenish May.

TABLE 4.—DISTRIBUTION OF SEEDS IN LARGE AND SMALL RHENISH MAY APPLES

Size-groups	Number of apples	Distribution of seeds						Average seed content
		Normal		Below normal		Above normal		
		Percent	Percentage of total	Percent	Percentage of total	Percent	Percentage of total	
Large...	2398	10	9.0	30.0	19.0	60.0	72.0	11.65
Small....	1009	10	13.3	72.4	58.1	17.6	28.6	7.55

SHOCKLEY

The third of the three varieties standing highest in seed production was Shockley. The multiplication of seeds in this variety was so pronounced that it was really in a class by itself. As with other varieties, the fruits were divided into two size-groups; each group contained 177 apples. There were no departures from normal in number of cells; each fruit had five. Unlike the other varieties there was, in Shockley, but very little difference in seed distribution between large apples and small apples. The tendency to multiplication was about the same in all fruits, and appeared as a well-established varietal characteristic. Averages of seeds to each fruit and seed distribution are shown in Table 5.

TABLE 5.—DISTRIBUTION OF SEEDS IN LARGE AND SMALL SHOCKLEY APPLES

Size-groups	Number of apples	Distribution of seeds						Average seed content
		Normal		Below normal		Above normal		
		Number	Percent	Number	Percent	Number	Percent	
Large...	177	4	2.26	21	11.86	152	85.88	15.04
Small....	177	7	3.96	19	10.73	151	85.31	14.59

The total number of ovules in all fruits was 6,536, an average of 18.5 for each fruit. As between the two size-groups, the large apples had 3,298, or 50.5 percent, and the small apples 3,238, or 49.5 percent, a nearly equal distribution. Of the total ovules 80.3 percent developed into seeds; and here, also, the division between large and small fruits approximated equality. The lowest number of ovules in any fruit was 10 in one small fruit. Three large fruits and one small fruit had each 11 ovules, and two large and five small had each 12. At the other extreme, one large fruit had 27 ovules, 21 of which developed into seeds, and one small fruit had 27 ovules, all of which became seeds. Two large fruits had each 26 ovules: one of these developed 24 seeds, the other 22. Four fruits had 25 ovules each with an average of 21 seeds. The maximum frequency of ovules falls on 20, there being thirty-one large apples and thirty-six small apples having each this number. These apples having 20 ovules each showed wide range in seed development. Of the large fruits, one had 1 seed, one had 2, and one had 5; and at the other extreme, three developed the total of 20 each, two had 19 each, and five had 18 each. Among the small apples having 20 ovules, four had no seeds; one had 11 seeds, two had 13 each, and nine had the full complement of 20 each. Aside from the four apples just referred to as having 20 ovules each and no developed seeds, were two others in the same group that were seedless; one of these had 17 ovules, the other 15. Some of the ovules in these six seedless fruits had enlarged the integuments somewhat, but none approached the size of mature seeds and all were perfectly flat, with nothing to indicate any activity in the direction of embryo development.

In order to indicate the position with regard to the size and weight of these parthenocarpic fruits as compared with other apples of the same group that stand high in seed production, six apples, each having twenty ovules, all represented by apparently perfect seeds, were taken at random and are shown in comparison with six seedless fruits in Table 6.

TABLE 6.—COMPARISON OF SEEDLESS FRUITS WITH FRUITS OF HIGH SEED PRODUCTION AS TO SIZE AND WEIGHT: SHOCKLEY

	Aver. weight in grams	Aver. diameter (mm.)	
		Long	Transverse
Six seedless fruits	102.75	49	64
Six fruits with 20 seeds each	94.49	51	58

It here appears that the parthenocarpic fruits were not the smallest in the group, as they exceeded an equal number of fruits that were highly productive of seeds, both in weight and in transverse diameter. The stimulus of the assumed pollination developed fruits of good size in the absence of fertilization. Fig. 1 shows abnormal seed production in Shockley.

HUNTSMAN

One other variety may be referred to here, the Huntsman, not so much because of its high seed content, altho one fruit reached a maximum of 18 seeds, but because of the symmetry of parts, the very open character of the core, the size and uniformity of cells, and the breadth of carpels. The variety was represented by 731 large fruits and 530 small. The average seed content of the large apples was 7.97; of the small apples, 6.66. Over 11 percent of the fruits had 11 or more seeds each, bringing the variety to fourth place on the list in this particular. It was exceeded by Shockley, Rhenish May, and

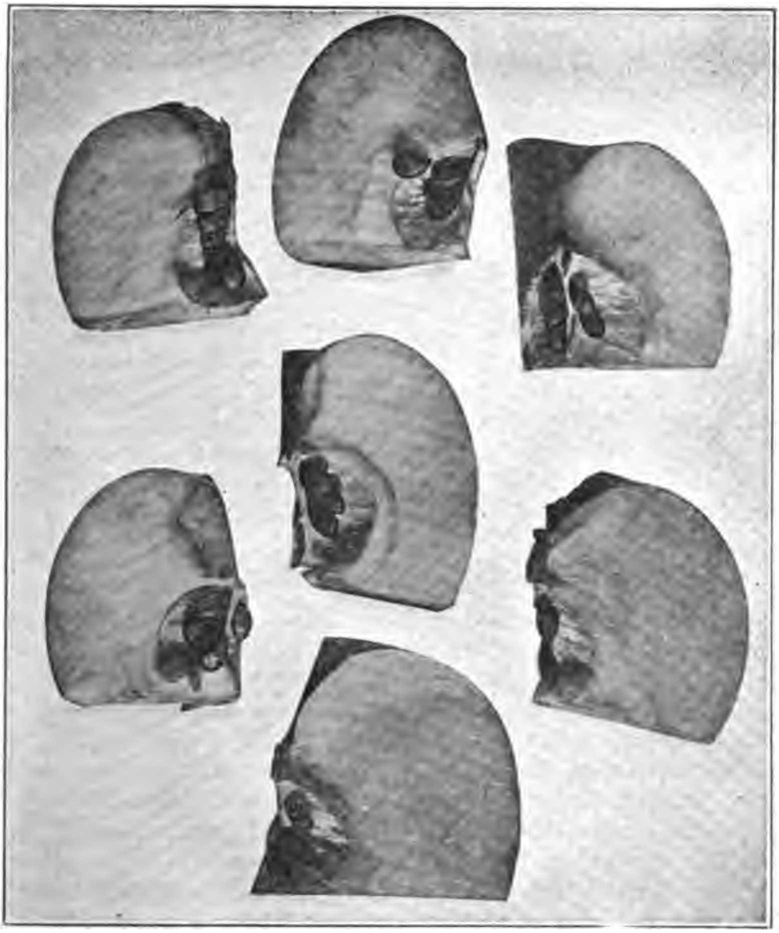

FIG. 1.—SEED PRODUCTION IN SHOCKLEY. PORTIONS OF FRUITS SHOWING NUMBER AND ARRANGEMENT OF SEEDS IN VARIOUS CARPELS

Winter Rambo, percentages for which have been given. The one fruit that had 18 seeds was photographed in section to show regularity of cells and high seed content; there were six cells, each with 3 plump seeds. This apple weighed 156 grams, and measured 54 mm. in longitudinal diameter and 72 mm. in transverse diameter. A section of the fruit appears in the front cover illustration.

VARIETIES LOW IN SEED PRODUCTION

Of the least productive varieties, Collins had the lowest seed content of any of the varieties examined. The 261 large apples had an average of 4.09 seeds; the maximum of nine was reached by 5 fruits, 16 fruits had only one seed each, and 48 had two each; three were seedless. The 150 small apples averaged 2.8 seeds; this was the lowest average found for any group. Four fruits had seven seeds each; this was the maximum for the group. Twenty-two had one seed each; 40 had two each, and 12 fruits were seedless. The apples of this small size-group were well above the size limit for No. 1 apples, as is shown by the average transverse diameter of 68 mm. and by the average weight, 134 grams.

Next above Collins in seed production was Minkler. In the large size-group of this variety there were 863 apples, which produced 3,694 seeds, an average of 4.28 to each fruit: 4 fruits had each the maximum of ten seeds, 55 had one seed each, 99 had two seeds each, and 20 were without seeds. The apples of this group had an average transverse diameter of 73.31 mm., and the average weight was 170.85 grams.

The small size-group numbered only 54 apples with an average of 3.65 seeds to each apple: two fruits had eight seeds each, the maximum for the group, and three fruits were seedless.

SEED PRODUCTION IN THE REMAINING VARIETIES

The twenty-six varieties that have not been specifically mentioned had various seed averages. In fourteen of them the range of averages was between 5 and 8 seeds to each fruit and in twelve it was between 8 and 11. With two exceptions the groups of large apples had distinctively greater seed averages than the groups of small apples. The two exceptions were Shockley, already mentioned in detail, in which the difference in size-groups was very slight, and McMahon. In this latter variety the number of apples was 200 for each group. The group of large apples had an average of 7 seeds to each fruit and the group of small apples an average of 7.75 seeds. The small apples also reached a higher maximum: two fruits had 14 seeds each, while only one fruit, in the group of large apples, reached a maximum of 13.

SIZE OF FRUIT IN RELATION TO THE PERCENTAGE OF OVULES DEVELOPED AS SEEDS

Another method of determining the relative seed production of large apples and small apples is by comparing the number of developed seeds in each of the two groups for each variety. Records obtained from twenty-one varieties are presented in Table 7, showing for each size-group the number of apples, the number of cells, the normal ovule content, allowing two to each cell, the number of ovules actually present, the excess above normal, the number of good seeds, the aborted seeds, and the percentage of ovules actually present that developed as seeds.

TABLE 7.—OVULE PRODUCTION IN ORCHARD VARIETIES

Variety	Number of apples	Number of carpels	Ovules					
			Normal number	Number found	Excess	Number developed	Number undeveloped	Percentage developed
			Large Apples					
Bailey Sweet	200	1001	2002	2288	286	1846	442	80.68
Collins	261	1303	2606	2606	...	1067	1539	40.94
Crawford	200	989	1978	2019	41	1294	725	64.09
Fameuse	200	1000	2000	2003	3	1303	700	65.05
Golden Ball	200	1002	2004	2114	110	1888	226	89.31
Hibernal	200	1000	2000	2008	8	1192	816	59.36
Indian	200	1000	2000	2156	156	1430	726	66.32
Isham	200	1000	2000	2052	52	1180	872	57.50
Mammoth Black Twig	200	1001	2002	2002	...	1036	966	51.74
McClellan	200	999	1998	2010	12	1627	383	80.94
McMahon	200	998	1996	2208	212	1400	808	63.40
Osceola	200	1001	2002	2157	155	1862	295	86.32
Polische Jungfrau	200	1002	2004	2339	335	2073	266	88.62
Rome	200	1002	2004	2029	25	1479	550	72.89
Shockley	177	885	1770	3298	1528	2665	633	80.80
Tolman	200	1004	2008	2034	26	1628	406	80.03
Wealthy	513	2566	5132	5135	3	4260	875	82.96
Willow	150	788	1576	1595	19	1235	360	77.43
Winter Rambo	550	2950	5900	6778	878	5488	1290	80.96
Wolf River	200	1001	2002	2167	165	1823	344	84.12
Wythe	200	1000	2000	2321	321	1948	373	83.92
Total	4851	24492	48984	53319	4335	39724	13595	74.50[1]
			Small Apples					
Bailey Sweet	199	995	1990	2117	127	1645	472	77.70
Collins	150	742	1484	1484	...	420	1064	28.30
Crawford	200	979	1958	1979	21	1051	928	53.10
Fameuse	200	1000	2000	2002	2	1036	966	51.74
Golden Ball	200	1001	2002	2066	64	1794	272	86.83
Hibernal	200	998	1996	2011	15	1148	863	57.08
Indian	200	1000	2000	2020	20	809	1211	40.04
Isham	200	1000	2000	2026	26	1066	960	52.61
Mammoth Black Twig	200	997	1994	1994	...	724	1270	36.30
McClellan	200	999	1998	2004	6	1498	506	74.75
McMahon	200	998	1996	2295	299	1551	744	67.58
Osceola	200	1000	2000	2014	14	1341	673	66.58
Polische Jungfrau	200	1001	2002	2149	147	1729	420	80.46
Rome	200	1000	2000	2009	9	1196	813	59.53
Shockley	177	885	1770	3238	1468	2584	654	79.80
Tolman	200	1003	2006	2006	...	1362	644	67.89
Wealthy	500	2498	4996	5002	6	3978	1024	79.52
Willow	200	1026	2052	2113	61	1558	555	73.73
Winter Rambo	500	2603	5206	5540	334	4148	1392	74.87
Wolf River	200	1000	2000	2150	150	1629	521	75.76
Wythe	200	999	1998	2166	168	1673	493	77.23
Total	4726	23724	47448	50385	2937	33940	16445	67.36[1]

[1] Average.

The number of large apples was 4,851; of small apples, 4,726. In all but three of the varieties the numbers of ovules present in the groups of large fruits were higher than in the groups of small fruits. The exceptions to the rule were: Hibernal, in which variety the 200 fruits in the small size-group had three more ovules than had the 200 apples in the large size-group, a difference so small as to bring the groups practically to equality; MacMahon, in which the group of small apples exceeded the large in total number of ovules by eighty-seven; and Willow, in which, taking into consideration the fact that the group of small apples exceeded the large by fifty in number of fruits, there was an excess of thirteen ovules for the small group. Of those varieties in which large apples exceeded small apples in numbers of ovules, Fameuse had the least difference and Winter Rambo the greatest. The average difference for all varieties approximated one hundred.

Some varieties exhibited little tendency to increase in number of ovules above the normal; others had the tendency strongly marked. In Collins and Mammoth Black Twig there was no excess in either size-group; in Tolman there was no excess in the small size-group, but an excess of twenty-six in the large size-group. All others had some excess in both groups, ranging, in the groups of large apples, from three for Fameuse and Wealthy to 1,528 for Shockley, and in the groups of small apples, from two for Fameuse to 1,468 for Shockley.

The percentages of ovules found present that were followed by plump and apparently viable seeds are, perhaps, the best gage of the relative seed-producing capabilities of the large and the small apples. Of the twenty-one varieties under consideration, all but one had the higher percentages of seeds developed in the groups of large apples. The one exception was McMahon, which had 63 percent of the ovules developed into good seeds in the group of large apples, and 68 percent thus developed in the group of small fruits. Percentages for the list of varieties other than McMahon ranged, for the groups of large apples, from 41 percent for Collins to 89 percent for Golden Ball. Half the varieties had percentages of 80 or above; others were somewhat less, but the average for the twenty varieties was 75 percent. On the other hand, the range of percentages of plump seeds for the groups of small apples was between 28 for Collins and 87 for Golden Ball, with an average for the twenty varieties of 67. In some varieties the differences between groups were small, as for example, Hibernal with a percentage of 59 for large apples and 57 for small, or Shockley with 81 percent for large and 80 percent for small. In others the differences were considerable, as in Mammoth Black Twig with 52 percent for large and 36 percent for small, or Indian with 66 percent for large and 40 percent for small. For the small apples of the twenty varieties taken together, the average of seeds developed was 67 percent of the possible as against 75 percent for the large apples.

In separating large apples from small apples for the groups considered above, a gap of 5 mm. was left between, that is to say, the minimum transverse diameter admitted to the group of large apples was 5 mm. more than the maximum transverse diameter included in the group of small apples. To test the effect of greater size difference between groups, the 100 largest Winter Rambo apples were selected for comparison with the 100 smallest of the same variety. The original groups of Winter Rambo numbered 550 large and 500 small, a sufficient number for a fair test of extremes.

These selected centenary groups ranged in transverse diameters as follows: the large apples from a minimum of 72 mm. to a maximum of 87 mm., with an average of 75 mm.; the small apples from a minimum of 40 mm. to a maximum of 52 mm., with an average of 48 mm.; the gap between groups was 20 mm., and the averages differed by 27 mm. The averages for the groups are tabulated below:

TABLE 8.—COMPARISON OF CENTENARY GROUPS OF LARGE AND SMALL WINTER RAMBO APPLES

Size-group	Aver. weight in grams	Average diameter in mm.		Aver. No. good seeds	Aver. No. undeveloped ovules	Percentage of ovules forming seeds
		Long	Transverse			
Large.....	167	59	75	10.64	2.53	81
Small.....	57	39	48	6.49	3.24	67

In the original group of 550 large apples the average seed content was 9.98; in this group restricted to the 100 largest it was 10.64, an increase of nearly 7 percent, and there was a corresponding increase in the number of ovules that did not develop. The percentage of ovules forming seeds was the same in both groups.

In the group of 500 small apples the average seed content was 8.3. The 100 smallest apples of this group had a seed average of 6.49, nearly 22 percent less than that of the full group. The increase in undeveloped ovules was over 14 percent and the decrease in percentage of seeds formed was about 8 percent. As between the centenary groups, the percentages of ovules developing into good seeds were 81 for the large apples and 67 for the small apples.

This comparison between the extremes in size found in apples of one variety confirms the results obtained in the analysis of seed production for all the varieties and strengthens the evidence which, taken together, appears to establish the fact that large apples develop a considerably larger proportion of the ovules they contain than do small apples.

In Table 7 is reported the ovule production of twenty-one varieties represented by 9,577 apples nearly equally divided into two groups on the basis of size. Examination in detail of the ovule and seed content of these apples indicates in a positive way that large apples are superior to small apples in seed production. The large apples contained nearly 6 percent more ovules than did the small apples, the total of seeds produced was 17 percent greater, and the percentages of ovules developed into seeds were, with the one exception cited, higher for the groups of large apples than for those of small apples.

SPECIES OF MALUS

The fruiting forms of the genus *Malus* included in the record of seed production number twenty-five. They represent seventeen named species and six classed as varieties, besides two, the Hyslop and Yellow Siberian Crabs, carried under their common names. There is much confusion in the nomenclature of the species of the genus and the taxonomic rank of some of our forms is uncertain, and cannot be definitely determined until a complete monograph of the genus is available. Three of the forms, namely, *Malus Iòensis,* the wild crab of the middle west, *Malus Soulardi,* the Soulard Crab, and *Malus fusca,* the Oregon Crab, are native. *Malus Arnoldiana* is a seedling of *Malus floribunda* originated at the Arnold Arboretum several years ago. *Malus prunifolia* var. (856) also originated at the Arnold Arboretum from seed collected in Japan in 1892 by Dr. C. S. Sargent. The names with descriptions of these two have not yet been published, but doubtless will be in the near future. It is probable that one or two of the other forms are seedlings having origin in this country, but with these definite and possible exceptions the forms in the list are of European or Asiatic origin.

The fruits of each species or variety were weighed and the average weight was recorded. Each individual was measured with calipers for longitudinal and transverse diameters. It was then cut transversely and record made of the number of carpels and the number and distribution of developed seeds and undeveloped ovules. The aggregate of fruits examined was 6,642, varying for the different lots from 22 for *M. fusca* to 1,200 for *M. Ringo sublobata. M. fusca* had small representation because but few fruits were available; all others had 100 or more fruits. The average weight for all fruits was 9.96 grams; if the two large crabs, Hyslop and Soulard, are eliminated, this average drops to 7.46 grams. Five of the forms had fruits which averaged less than one gram in weight, and four, besides the two crabs just mentioned, had fruits that averaged above 10 grams. As a means of giving a right impression of the range in size and form and the relative sizes of the different crabs, a single fruit of each of the twenty-five forms is shown, natural size, in Figs. 2 to 7, inclusive.

Table 9 gives the distribution of carpels, the seed distribution, and the percentage of ovules forming good seeds for each of the twenty-five crab-like forms.

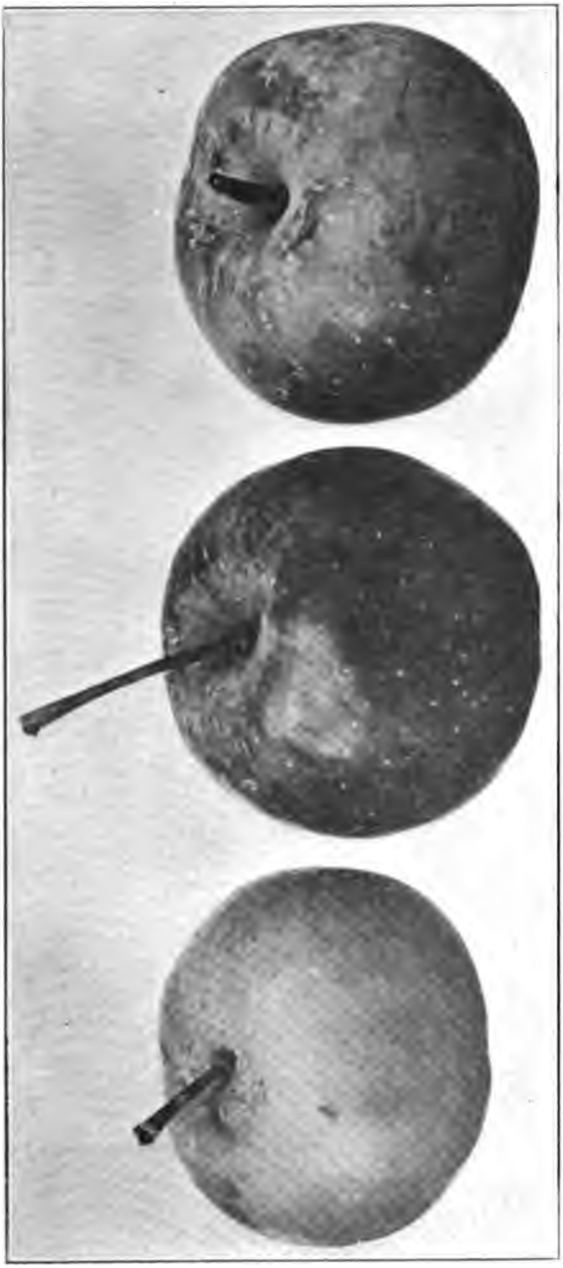

FIG. 2.—CRABS, NATURAL SIZE. LEFT TO RIGHT: *Malus Soulardi*, HYSLOP CRAB, *Malus Malus flore pleno*

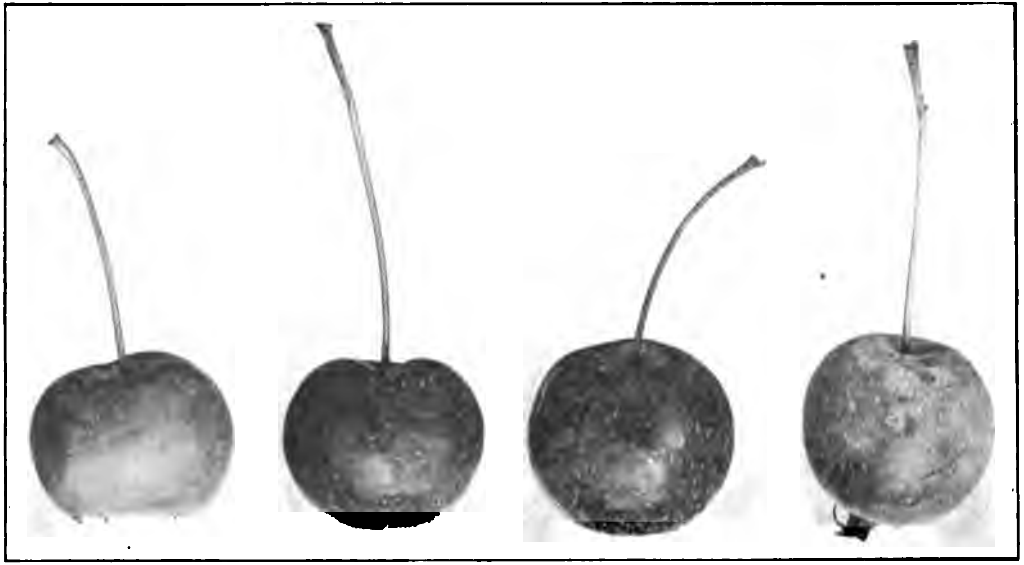

FIG. 3.—CRABS, NATURAL SIZE. LEFT TO RIGHT: *Malus baccata* (RED FRUIT), *Malus baccata* (RED FRUIT, LATE), *Malus baccata maxima*, *Malus prunifolia* var. (838)

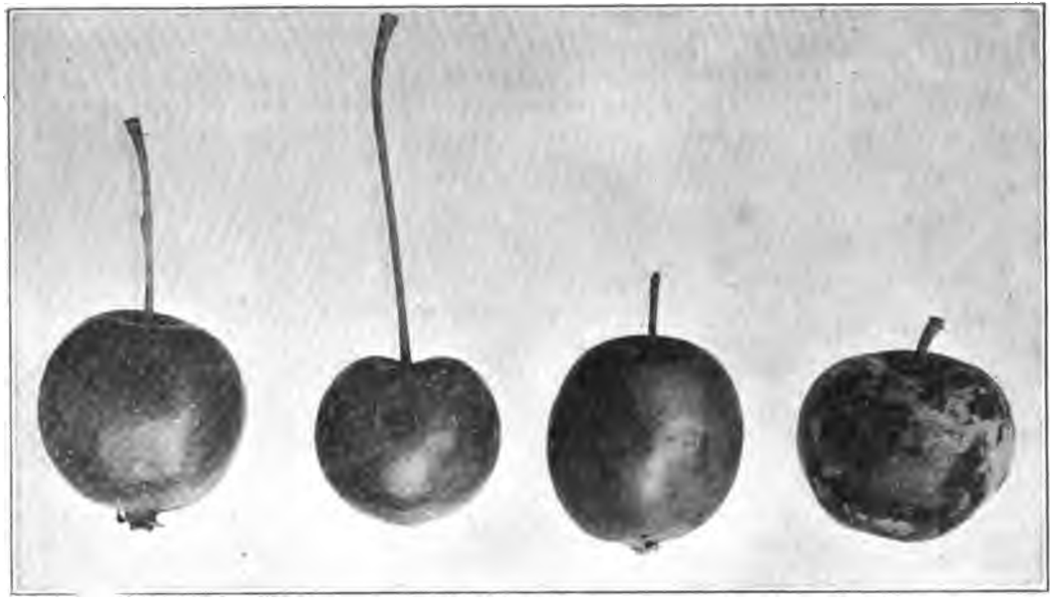

FIG. 4.—CRABS, NATURAL SIZE. LEFT TO RIGHT: *Malus prunifolia* var. (19651), ***Malus Malus*** var., ***Malus Ringo sublobata, Malus microcarpa***

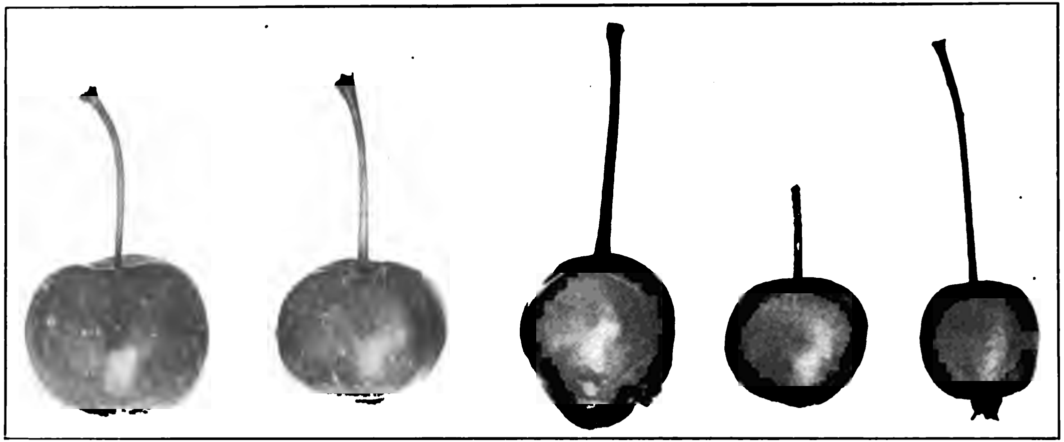

FIG. 5.—CRABS, NATURAL SIZE. LEFT TO RIGHT: *Malus Siberica frutico coccinea, Malus Scheideckeri, Malus spectabilis* No. 615, *Malus Bingo* (840), *Malus prunifolia* var. (856)

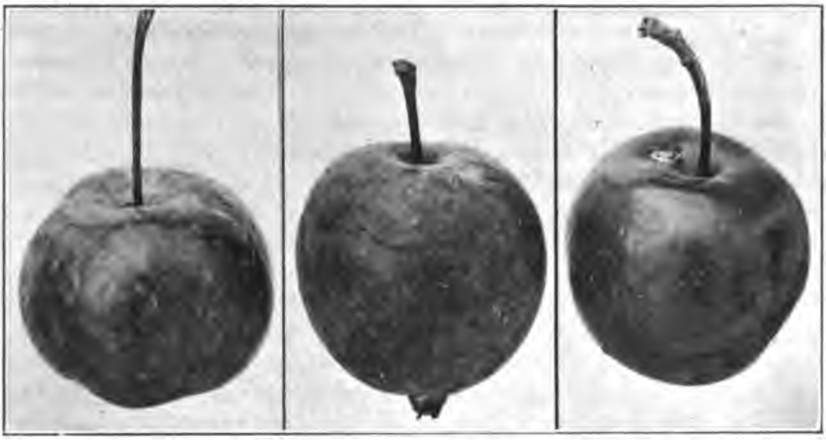

FIG. 6.—CRABS, NATURAL SIZE. LEFT TO RIGHT: YELLOW SIBERIAN CRAB (857), *Malus fastigiata bifera, Malus Ioensis*

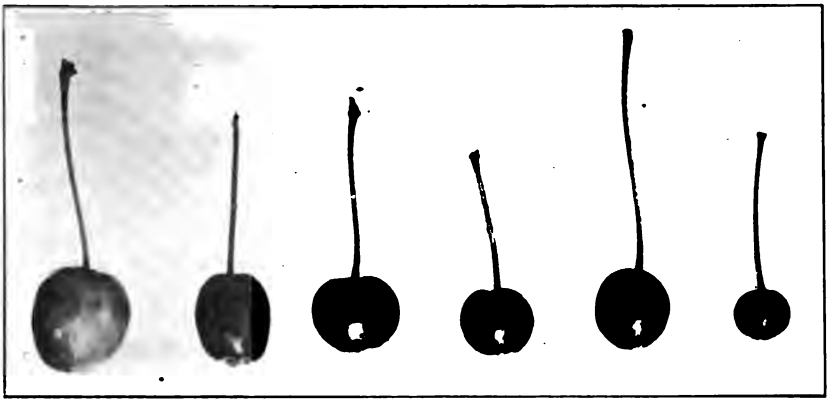

FIG. 7.—CRABS, NATURAL SIZE. LEFT TO RIGHT: *Malus Arnoldiana, Malus fusca, Malus floribunda, Malus Sargenti, Malus atrosanguinea, Malus Toringo* (19664)

NUMBER AND DISTRIBUTION OF CARPELS

There were wide differences among species in number and distribution of carpels; the range in numbers was from 2 to 12. The minimum of two carpels was found in two species, *M. Arnoldiana* and *M. Sargenti. M. Arnoldiana,* represented by 100 fruits, had two fruits each with two carpels; in both, the ovules were as expected, two in each cell; one developed three plump seeds, the other only one. *M. Sargenti,* represented by 223 fruits, had one fruit with only two carpels, containing four ovules; one good seed developed in each carpel. At the other extreme *M. spectabilis* (No. 615) had one fruit with twelve carpels and another with eleven. In these two cases the large number of carpels was due to the appearance of a second whorl of carpels superposed upon the normal whorl. The fruit having twelve carpels had seven in the basal whorl and five in the upper whorl: these twelve carpels contained thirty-one ovules, ten of which developed into plump seeds, and of this ten, three were in the carpels of the superposed whorl. Nine other fruits had the additional whorl represented by one or two carpels and these carpels all contained developed seeds. The remaining 89 fruits of this species had carpels distributed as follows: 13 with the normal of five, 49 with six carpels each, 22 with seven, and 5 with eight each; but in all these fruits the additional carpels were crowded into the one whorl.

Those fruits possessing the secondary whorl of carpels gave external evidence of its presence in enlargements which appeared as protuberances projected vertically about the basin. These protuberances coincided with those carpels in which seeds were developed, and for those cases in which the seed development was distributed around the whorl, the calyx appeared as the bottom of a deep, irregular basin, while for those in which only one or two seeds, in close proximity, on one side, were developed, the resulting protuberance gave a one-sided fruit with the calyx appearing as if on the side of the apple. See central fruit in Fig. 5.

Two other species showed a strongly developed tendency to multiplication of carpels; these were *M. Malus flore pleno* and *M. Scheideckeri*. The first had 3 fruits with a maximum of nine carpels, 8 fruits with eight carpels each, 21 with seven each, 49 with six each, and only 19 with the normal five carpels. The second had a maximum of eight carpels, represented by one fruit; 82 fruits had each seven carpels, and 309, or 51.5 percent of the total of 600, had each six carpels. Two hundred and six fruits had each the normal of five carpels, and two fruits had only four carpels each. The range for the first species was 5 to 9, for the second, 4 to 8.

Considering the aggregate of 6,642 fruits representing the twenty-five crab forms, it appears that 4,565 fruits, or 68.73 percent, had each the normal five carpels. With numbers of carpels less than five there were 1,483 fruits, or 22.33 percent; and the aggregate of fruits with numbers of carpels above normal was 594, or 8.94 percent.

The two crabs with fruits of large size, Hyslop and Soulard, exhibited no departures from the normal of five carpels. All other crabs showed variation in numbers of carpels: twelve varied only in the direction of diminished numbers, four only in the direction of increased numbers, and seven showed variations in both directions.

The species bearing very small fruits tended more strongly to reduction in numbers of carpels than did the species having larger fruits; for example, compare 100 fruits each of the four species *M. Toringo, M. Sargenti, M. floribunda,* and *M. atrosanguinea,* whose fruits averaged less than one gram in weight, with equal numbers of the four forms *M. baccata* (red fruit), *M. baccata* (red fruit, late), *M. baccata maxima,* and *M. prunifolia* var. (838), whose fruits ranged in average weight from 6.62 grams to 9.63 grams. The distribution of carpels in these forms of *Malus* was as follows:

	Number of Carpels			
	Three	Four	Five	Six
Small-fruited species	61	271	68	..
Larger-fruited species	1	7	391	1

For the small-fruited species 83 percent of the fruits had numbers of carpels less than five, while only 17 percent had the normal number. For the larger-fruited species only 2 percent of the fruits had less than five, 97.75 percent were normal, and one fruit, or ¼ of 1 percent, had one more than the normal of five.

While it was generally the case in this crab group that the very small fruits showed the greatest tendency to reduction in numbers of carpels, there were exceptions, as in the case of one variety of *M. prunifolia,* the 600 fruits of which had an average weight of 10.64 grams and in which 506 fruits, or 84.33 percent, had numbers of carpels less than five.

SEED PRODUCTION

The averages of seeds contained in fruits of the twenty-five species and varieties of *Malus* included in the list ranged from 1.32 for *M. fusca,* which was represented by only 22 fruits, and 2.02 for *M. atrosanguinea,* represented by 100 fruits, to 7.8 for *M. Malus flore pleno.* For all forms considered together the aggregate of seeds produced was 28,050, which gives an average of 4.22 seeds to each fruit. The range shown was rather wide, and the general average decidedly lower than for the small fruits of orchard varieties. In distribution the range was from 0 to 14. There were 94 parthenocarpic fruits, representing nine of the species. Seventy-eight, or nearly 83 percent of these, occurred in the variety *sublobata* of the species *Ringo* (19689); the remaining 16 were found in numbers from 1 to 4 in eight other species. Fruits with one seed each numbered 574; these were distributed among nineteen of the species in numbers from 1 for *M. Ringo* and *M. Siberica frutico coccinea* to 312 for the variety of *M. Ringo,* which is so productive of parthenocarpic fruits. With two seeds each there were 1,037 fruits, with three seeds each, 1,130 fruits: this was the maximum frequency. Numbers for higher seed content decreased moderately at first and then more rapidly until the maximum of fourteen was reached by one fruit of *M. Malus flore pleno,* This species had 2 fruits with thirteen seeds each, 6 with twelve seeds each, and 4 with eleven each. Four other species had one fruit each reaching a maximum content of eleven seeds. With ten seeds each, there were 65 apples, less than 1 percent of the total number of fruits examined. Eight species reached their maxima at ten seeds, and only five species had more than this number.

In *M. fusca* the highest number of seeds was three in each of two fruits, but the number of fruits of this species was too small to warrant the assumption that this maximum is normal. Next above *M. fusca* two species, *M. atrosanguinea* and *M. floribunda,* had the number five as the maximum of seeds produced; each was represented by 100 fruits; the former had one fruit, the latter three fruits, each of which had five seeds.

As with seed production in the orchard varieties, some of these crab forms tended to concentrate within a small range, as between 1 and 5 for *M. atrosanguinea* and *M. floribunda,* two closely related species; some tended to wider range, as 2 to 14 for *M. Malus flore pleno,* or 0 to 11 for *M. baccata* (red fruit) and *M. Ringo.* Some of the species had very small seeds, and in some the seeds were nearly as large as the average in orchard varieties. The size and shape of the seeds of the twenty-five crab-like forms are shown in Fig. 8 (natural size).

NUMBERS OF OVULES

It developed in examining the apples here considered that for most species the normal complement of two ovules to the carpel, or ten for an apple with five carpels, held with great regularity. In twelve of the species not a single departure in either direction from the expected normal was found. This group of twelve species contained 2,947 fruits which had an aggregate of 13,557 carpels and exactly double this number of ovules; each carpel had its full complement of two, no more and no less. Approximately one-half the ovules developed into seeds that appeared normal and viable; the seeds numbered 13,622, representing 50.24 percent of the contained ovules. The undeveloped ovules numbered 13,492, representing 49.76 percent of the total number; these were of all sizes, some so small as to require a hand lens for clear determination, others with integuments developed to nearly full size, but perfectly flat and containing no embryos. Nine other species had ovules in excess of the normal in numbers ranging from 1 to 300. The total of ovules above normal was 421 distributed in 158 fruits. Of this number 300 were found in fruits of *M. spectabilis* and 81 in fruits of *M. Malus flore pleno,* two species that are abnormal in most flower and fruit characters. Excluding these two species, the other seven species of this group had an excess above normal of 40 ovules distributed in 35 fruits.

M. spectabilis far exceeded all others in number of surplus ovules. This species had 300, or 71.25 percent, of the total surplus, and these

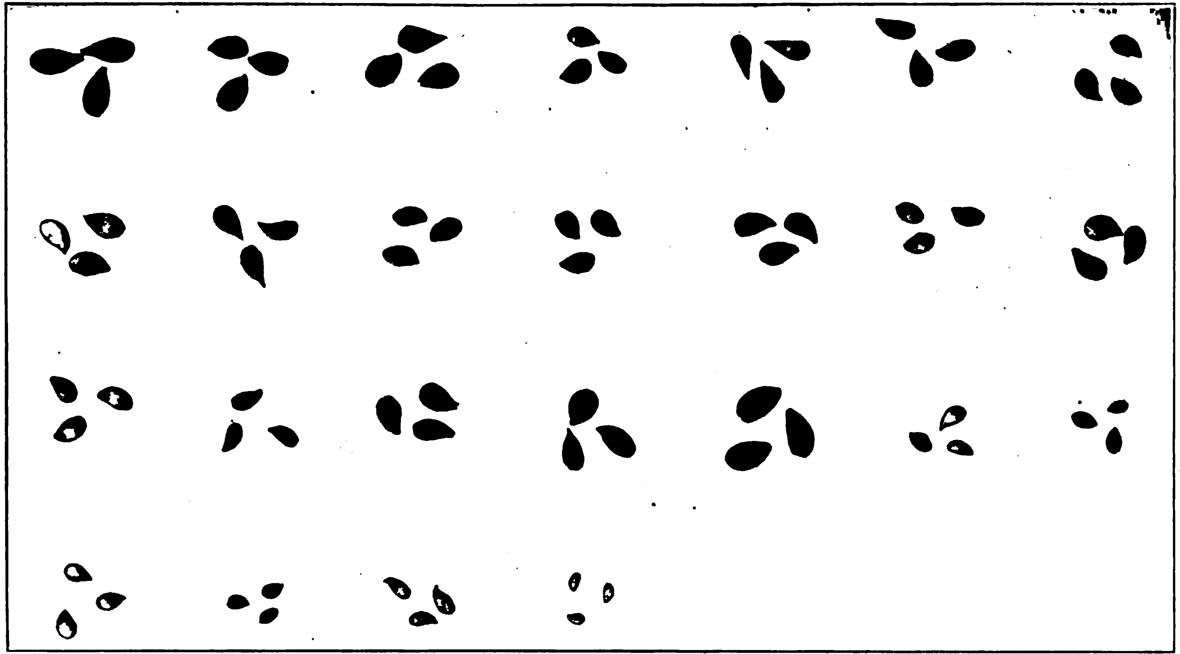

FIG. 8.—SEEDS OF MALUS FORMS INCLUDED IN THE CRAB GROUP, NATURAL SIZE. LEFT TO RIGHT: TOP ROW, *M. Soulardi*, HYSLOP CRAB, *M. Malus flore pleno*, *M. baccata* (RED FRUIT), *M. baccata* (RED FRUIT, LATE), *M. baccata·maxima*, *M. prunifolia* var. (838); SECOND ROW, *M. prunifolia* var. (19651), *M. Malus* var., *M. Ringo sublobata*, *M. microcarpa*, *M. Siberica frutico coccinea*, *M. Scheideckeri*, *M. spectabilis* No. 615; THIRD ROW, *M. Ringo* (840), *M. prunifolia* var. (856), YELLOW SIBERIAN CRAB, *M. fastigiata bifera*, *M. Ioensis*, *M. Arnoldiana*, *M. fusca*; FOURTH ROW, *M. floribunda*, *M. Sargenti*, *M. atrosanguinea*, *M. Toringo*, dwarf, (19664)

were distributed in 91 of the 100 fruits examined in numbers varying from one to eleven.

The 81 surplus ovules in *M. Malus flore pleno* were distributed i 32 fruits in numbers ranging from one to six.

The maximum number of ovules was 25 in a fruit of *M. spectabil* having seven carpels: four of the carpels contained 4 ovules each an three carpels had 3 each. The maximum for individual carpe was 5 ovules; this number was found in several cases in this sam species. Where 4 or 5 ovules are present, they are arranged in tw ranks along the placenta at the inner margin of the carpel.

In the four remaining species departures from the normal in th direction of decrease in numbers were recorded. These shortages wer small; 16 for *M. Scheideckeri,* 6 for *M. Malus* var., 4 for *M. Sargenti* and 2 for *M. Ringo sublobata.* This is a total of 28 below the expecte total of 22,724 ovules for 2,244 apples having 11,362 carpels.

In two or three cases the two ovules of a single carpel were suppressed, but for all others one of the pair was absent or so undevelope that its presence could not be detected.

The rarity of suppression of ovules is most clearly brought out by comparing the number recorded as suppressed with the total of ovules present. The 6,642 apples of all species contained 32,192 carpels, and with two ovules to each carpel, 64,384 would be the expected total of ovules. The actual number recorded as present was 64,777, but this included 421 ovules in excess of normal. Deducting this number leaves 64,356, which number, if increased by 28, the total of ovules suppressed, will equal the normal for the fruits considered. For the apples examined, approximately one ovule in 2,300 was suppressed; the percentage is sufficiently low to indicate that suppression is of rare occurrence.

COMPARISON OF ORCHARD AND CRAB-LIKE VARIETIES IN OVULE AND SEED PRODUCTION

In neither size-group of orchard varieties were deficiencies in ovule production recorded, but in all varieties, except Collins and Mammoth Black Twig in both size-groups and Tolman in the small size-group, ovules were in excess of normal in numbers ranging from two for Fameuse in the small size-group and three for the same variety in the large size-group, to 1,528 for Shockley in the large size-group and 1,468 for the same variety in the small size-group. The variety ranking next to Shockley in number of ovules in excess of normal was Winter Rambo, which had 878 in the large size-group and 334 in the small size-group, but this variety had more than three times as many large apples and nearly three times as many small apples as had Shockley, so that while there were 8.6 surplus ovules to each large apple in Shockley, there were only 1.6 surplus ovules ribution of fruits as to number of seeds

	3	4	5	6	7	8	9	1
2	21	28	13	8	2			
5	22	3	1					
9	44	61	80	115	119	93	51	1
6	118	115	128	83	38	22	2	
3	4	6	9	17	18	16	16	1
0	41	70	75	86	73	33	13	
8	26	29	3					
3	2							
5	46	62	51	25	18	18	8	
1	2	2	8	15	21	18	13	
7	39	48	40	30	4	3		
1	2	5	11	16	18	26	14	
3	5	7	16	18	20	14	13	
7	9	19	18	19	15	6	2	
2	52	153	138	131	53	25	7	
2	4	8	27	19	16	16	4	
7	244	133	72	42	8	4		
5	68	37	12	4				
6	187	114	60	11	4			
1	1	6	19	15	15	21	14	
8	141	96	44	19				
2	5	7	10	16	19	23	15	
5	6	8	13	19	22	24	14	
9	12	17	20	16	9	7	7	
0	29	25	12	7	1			

Distribution of fruits as to number

3	4	5	6	7	8	9	10
26	58	75	116	126	152	136	8
23	42	80	90	145	164	137	10
249	264	217	191	184	164	137	6
14	17	24	30	36	25	15	
6	9	2	2				
1	3	2	2	1		2	

to each large Winter Rambo apple. For the small apples the difference between the two was still greater. In Shockley, multiplication of ovules appeared as a well-established characteristic, and in this regard the variety is comparable with *M. spectabilis* among the crabs. With other varieties whose fruits have surplus ovules, the numbers are scarcely sufficient to suggest an established tendency towards multiplication, but rather that their appearance is more or less casual. However, comparison of the records for the twenty-one orchard varieties (Table 7) with those for the twenty-five crabs (Table 9) indicates clearly that production of ovules in excess of the expected normal is of much more common occurrence among orchard varieties than it is among the crabs.

The relative standing of orchard varieties and the wild or semi-wild forms of *Malus* in the matter of seed production is, perhaps, most clearly shown by comparing the percentages of ovules, actually present, that develop into seeds. Thus, the 4,851 large fruits of twenty-one orchard varieties contained 53,319 ovules and developed 39,724 seeds, or 74.5 percent; the 4,726 small fruits of the same varieties contained 50,385 ovules and developed 33,940 seeds, or 67.38 percent; or, taking the aggregate of apples from orchard varieties, the percentage of seeds that developed was 71.03, while for the 6,642 fruits of species of *Malus* the 64,777 ovules developed 28,050 seeds, or 43.3 percent. These percentages of aggregates, 53.3 percent for species of *Malus* and 71.03 percent for orchard varieties, show fairly well the relative seed-producing capacity of the two groups and are sufficiently separated to indicate in a positive way that orchard varieties are decidedly superior to wild species in seed production.

SEED PRODUCTION UNDER CONTROLLED POLLINATION

All fruits thus far considered in relation to seed production have developed from flowers open to pollination by natural agencies. That the insect agents did the work well and that weather agencies were not adverse may be assumed from the fairly full crops borne by the trees.

The question as to whether protection of flowers and the artificial application of pollen gives equal or greater seed production than does open pollination is naturally suggested, and brief mention of seed production in fruits developed from protected hand-pollinated flowers may be made here.

The fruits resulting from hand pollination of emasculated flowers protected by paper bags numbered 4,504 for the six seasons 1909 and 1911-1915, but of these fruits there were 643 for which the record is, in some detail, incomplete; these are omitted, leaving 3,861 fruits, the records from which are here considered. These fruits were separated into four groups according to parentage for the purpose of maintaining a distinction between and recording the behavior of the two classes of apples, orchard varieties and crab-like species of *Malus*, when crossed in different ways. At this time it is not the purpose to consider these combinations further than to show carpel and seed distribution and seed averages. The four classes of crosses were: orchard varieties × orchard varieties, represented by 833 fruits; orchard varieties × crab-like forms of *Malus*, represented by 857 fruits; crab-like forms of *Malus* × orchard varieties, represented by 1,967 fruits; and crab-like forms of *Malus* × crab-like forms of *Malus*, represented by 204 fruits. To these may be added 45 fruits resulting from self-pollinated flowers of crab-like forms of *Malus* and 12 fruits from selfed flowers of orchard varieties. These additional classes had small representation because most efforts to produce self-fertilized fruits have failed entirely. It is general thruout the genus *Malus* that stigmas of flowers of the very diverse forms do not readily accept their own pollen, and this characteristic is more commonly apparent among orchard varieties than it is among the less highly developed crab-like forms. As hybridity in plants tends strongly towards sterility, the prevalence of self-sterility in species and varieties of *Malus* indicates the probable hybrid nature of many of the forms. This, to the breeder, is a discouraging feature, because selfing is essential to determining the transmission and segregation of particular parental characters.

Records of carpel distribution with number and distribution of seeds for each of the classes of fruits resulting from controlled pollinations are brought together in Table 10. There is nothing in this table to indicate marked superiority in seed production of fruits developed from flowers artificially pollinated over fruits from flowers open to natural agencies for transfer of pollen. In the groups of naturally pollinated orchard varieties the average number of seeds to each fruit was for large fruits 8.27 and for small fruits 7.21, or for the two sizes combined, 7.85. For fruits from controlled pollinations, the 833 fruits of orchard varieties pollinated by orchard varieties had an average of 7.23 seeds to each fruit, and the 857 fruits of orchard varieties pollinated by crab-like species had an average of 7.45 seeds to each fruit; or, combining the two groups in which orchard varieties served as mother plants, the seed average was 7.35. These averages do not indicate that control of pollination exercised any marked influence upon seed content. Fruits of the twenty-five crab-like forms of *Malus* developed from open-pollinated flowers had an average of 4.22 seeds to each fruit. The 204 fruits of crab-like forms which resulted from hand pollinations with pollen from other crab forms had an average of 5.69 seeds to each fruit, while the 1,967 crab fruits developed from flowers hand pollinated with pollen of orchard varieties had an average content of 4.74 seeds to each fruit; or, combining these groups in which the mother plants are crabs, the average was 4.83 seeds to each fruit. Here the averages for fruits from controlled pollinations are in advance of those for fruits from open pollinations, but the differences are not great, and when the disparity in numbers of fruits averaged in the different groups is considered, it appears that further investigation is needed before a stable basis for definite conclusions can be reached. It may be stated, however, that participation in the making and compiling of such records as we now have, together with study of the data, has given a rather definite impression that whether the pollination is open or controlled makes small difference in the proportion of ovules that develop as viable seeds.

CONCLUSIONS

1. From the foregoing study of seed production in apples it appears that the average number of seeds to each fruit is almost twice as great for orchard varieties as for fruits from crab-like forms of *Malus*. Dividing fruits of orchard varieties into two groups on the basis of size, it further appears that large apples exceed small apples in seed production, altho the difference is not nearly so great as is the difference in seed content between orchard varieties and crab-like forms.

2. The range in average seed production as exhibited by different varieties is wide with both orchard varieties and crab-like forms.

3. Departures from the normal of five carpels to each fruit occur with both orchard varieties and crab-like forms, but are much more frequent with crabs than with orchard fruits.

4. There are wide differences among individual varieties and species in seed-producing capacity, and the range in numbers of seeds in individual fruits is also wide.

5. The assumed normal of ten seeds to each fruit is likely to occur in a small percentage of orchard fruits, but rarely occurs in crab-like forms.

6. Capacity to produce seeds appears as a varietal characteristic.

7. Parthenocarpic fruits occur in orchard varieties and in species of *Malus,* but not in very great numbers.

8. There is great regularity in the appearance of ovules in normal numbers, that is, two in each carpel. Few cases of suppression of ovules occur; numbers in excess of normal are more common among orchard varieties than among crabs.

9. Comparison of seed production in fruits developed from flowers open to pollination by insects and in fruits from hand-pollinated flowers brings out only small differences; apparently seed production is not dependent upon the manner in which pollination is effected.

10. Considerable differences appear in seed production of individual fruits and of particular varieties, but averages of groups warrant the conclusion that the more highly developed orchard varieties exceed crabs in seed production and that, as between large and small fruits, large fruits produce the greater number of seeds.

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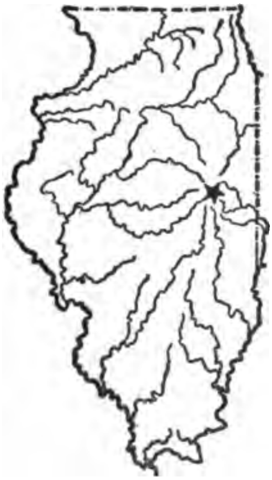
UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

BULLETIN No. 204

GERM CONTENT OF MILK
II. AS INFLUENCED BY THE UTENSILS

By M. J. PRUCHA, H. M. WEETER, and W. H. CHAMBERS



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GERM CONTENT OF MILK

II. AS INFLUENCED BY THE UTENSILS

By M. J. PRUCHA, Assistant Chief in Dairy Bacteriology
H. M. Weeter, Assistant in Dairy Husbandry, and
W. H. Chambers, Assistant in Dairy Bacteriology

INTRODUCTION

The interval during which milk will remain sweet is an important element of its value, and one for which the producer has been held mainly responsible. Milk sours because of the growth in it of plant life—bacteria. The problem of protecting the keeping quality of milk becomes one of preventing the entrance of bacteria, of destroying them after they enter, or of keeping them so cold as to check their growth. The first interest of the producer is to restrict the number of bacteria getting into the milk, so far as is consistent with the costs involved. To do this he must know the relative importance of the various avenues thru which they may enter.

Additions to our knowledge regarding the relative importance of the various avenues thru which bacteria enter milk have been furnished by a series of experiments conducted at the New York (Geneva)[1] and the Illinois[2] Agricultural Experiment Stations. The most striking result of these studies has been to establish the fact that ordinarily barns have little or no measurable influence upon the germ content of the milk produced in them.

The need of further study to determine the mode of entrance of the large number of bacteria that are regularly found in the public milk supply, being recognized, this investigation, begun in the fall of 1913, was directed toward determining the influence that the various utensils in which milk is normally handled exerts upon the germ content of the milk.

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[1] Harding, H. A., Wilson, J. K., and Smith, G. A. Milking Machines: Effect of Method of Handling on the Germ Content of Milk. N. Y. (Geneva) Agr. Exp. Sta. Bul. 317. 1909.

Harding, H. A., Wilson, J. K., and Smith, G. A. The Modern Milk Pail. N. Y. (Geneva) Agr. Exp. Sta. Bul. 326. 1910.

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Harding, H. A., and Wilson, J. K. A Study of the Udder Flora of Cows. N. Y. (Geneva) Agr. Exp. Sta. Tech. Bul. 27. 1913.

Ruehle, G. L. A., and Kulp, W. L. Germ Content of Stable Air and Its Effect upon the Germ Content of Milk. N. Y. (Geneva) Agr. Exp. Sta. Bul. 409, pp. 418-474. 1915.

[2] Prucha, M. J., and Weeter, H. M. Germ Content of Milk: I. As Influenced by Factors at the Barn. Ill. Agr. Exp. Sta. Bul. 199. 1917.

PREVIOUS STUDIES ON UTENSILS

In 1889, H. W. Conn[1] made the following comment on the influence of utensils upon bacterial contamination of milk: "Vessels in which milk and cream are to be kept are a great source of contamination of bacteria. The latter gather upon the sides and in the joints and develop in the minute portions of milk, grease, and other matter from which it is difficult to free the vessels completely by washing."

Five years later H. L. Russell,[2] in his studies on milk contamination, examined two covered pails. One pail was steamed for half an hour and the other was cleaned in the ordinary way but not steamed. The milk received into the sterilized pail had a germ content of 165 bacteria per cubic centimeter, while that received into the pail not steamed contained 4,265 bacteria per cubic centimeter. In commenting later on the contamination of milk by utensils, this author[3] states that "dirty vessels are a prolific source of trouble."

In 1898, Backhaus and Cronheim[4] observed that passing milk over a certain cooler raised its germ content from 11,500 to 33,000 bacteria per cubic centimeter. In 1904, Bergey[5] concluded from his studies on milk contamination that the greater portion of the bacteria with which milk becomes contaminated is derived from the utensils. In the following year, Erf and Melick[6] reported that cream separators flushed with hot water at night after being used, when used the following morning added to the germ content of the milk passing thru them, some millions of bacteria per cubic centimeter of milk. In 1906, Stewart[7] reported that the utensils invariably harbor a considerable number of bacteria. He found that it is difficult to free the utensils from germ life short of treatment with steam under pressure.

Russell and Hoffmann[8] found that when milk bottles were washed and steamed and allowed to stand twenty-four hours, the bacteria multiplied in the remnants of water resulting from the condensation of the steam.

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[1] Conn, H. W. Bacteria in Milk and Its Products. Storrs Agr. Exp. Sta. Bul. 4. 1889.

[2] Russell, H. L. Sources of Bacterial Infection and the Relation of the Same to the Keeping Quality of Milk. Wis. Agr. Exp. Sta. Ann. Rpt. 11, p. 152. 1894.

[3] Russell, H. L. Tainted and Defective Milks: Their Causes and Methods of Prevention. Wis. Agr. Exp. Sta. Bul. 62. 1897.

[4] Backhaus, W., und Cronheim, W. Über aseptische Milchgewinnung. Ber. Landw. Inst. Univ. Königbs., 1, Heft. 2, pp. 12-32. 1898.

[5] Bergey, D. H. Sources and Nature of Bacteria in Milk. Penn. Dept. of Agr. Bul. 125. 1904.

[6] Erf, O., and Melick, Chas. W. Care of Dairy Utensils. Kans. Agr. Exp. Sta. Bul. 131. 1905.

[7] Stewart, A. H. Cleansing of Milk Vessels: Relative Value of Washing Powders. Amer. Med., 2, pp. 241-244. 1906.

[8] Russell, H. L., and Hoffmann, Conrad. Bacteriological Test of Bottle-Washing Device. Wis. Agr. Exp. Sta. Ann. Rpt. 22, pp. 227-231. 1905.

The various studies upon the milking machines by Harrison,[1] by Hastings and Hoffmann,[2] Stocking and Mason,[3] Meeker,[4] and Harding, Wilson, and Smith[5] have shown that the germ content of milk may be astonishingly increased thru the influence of the milking machine, tho it is possible to keep the influence of the machine within fair limits provided it is properly handled.

METHODS OF STUDY

Washing of Utensils.—The cans used in this study were from two different dairies. In both dairies the method of washing was similar in that each can was placed in a vat containing one-percent warm solution of sodium-carbonate washing powder, and scrubbed with a brush. There were, however, some differences in the conditions and in the methods employed in the two dairies. In Dairy A the milk handled in the cans had usually a low germ content; the number of cans washed in the same lot of wash water was from 20 to 30; the amount of wash water used was 60 gallons, and the cans were rinsed after being washed. In Dairy B the milk handled in the cans invariably had a high germ content; from 60 to 80 cans were washed in the same lot of wash water; the amount of the water used was about 25 gallons, and the cans were not rinsed after they were washed.

All other utensils studied were washed in Dairy A. In the case of some of the utensils, such as the bottle filler, the above method of washing could not be employed; and in some of the experiments with cans, the method of washing was intentionally altered. Such changes are described in connection with the respective experiments.

The cans in Dairy A were of eight-gallon capacity; those in Dairy B were of five-, eight-, or ten-gallon capacity; and the bottles were the regular quart size.

Determining Number of Bacteria in Utensils.—Two methods were used in this study for determining the number of bacteria in the utensils. In the experiments reported in Part I a given quantity of sterile water, usually one liter, was poured into the utensil and after a thoro shaking, a sample of this water was taken and the number of bacteria in it determined. This obviously falls considerably short of demonstrating the full amount of germ life present in the utensils. In the experiments reported under Part II, samples were taken of the milk after it was actually poured into the utensils in the ordinary operations of the dairy, and the difference in the germ content of the milk handled in steamed utensils and that handled in unsteamed utensils was taken as the measure of the germ content of the unsteamed utensils. This method evidently more closely measures the true influence of the utensils upon the milk, but it is ordinarily a more difficult and expensive form of experimentation.

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[1] Harrison, F. C. Machine Drawn Versus Hand Drawn Milk. Centbl. Bakt. (etc.), 2 Abt., 5, 183-189. 1899.

[2] Hastings, E. G., and Hoffmann, Conrad. Bacterial Content of Machine Drawn and Hand Drawn Milk. Wis. Agr. Exp. Sta. Ann. Rpt. 24, pp. 214-223. 1907.

[3] Stocking, W. A., Jr., and Mason, C. J. Milking Machines: Part I. Effect upon Quality of Milk. Storrs Agr. Exp. Sta. Bul. 47. 1907.

[4] Meeker, E. B. Bacterial Efficiency of the Milking Machine. Penn. Agr. Exp. Sta. Ann. Rpt. for the year 1907-1908, Part II. pp. 146-159. 1908.

[5] Harding, H. A., Wilson J. K., and Smith, G. A. Milking Machines: Effect of Method of Handling on the Germ Content of Milk. N. Y. (Geneva) Agr. Exp. Sta. Bul. 317. 1909.

The plate method was used for counting the bacteria in these samples. Usually two or three dilutions were made from each sample, and three plates were poured from each dilution. Every count recorded in this study is an average of the counts from at least three plates. The medium used in making these counts had the following composition:

Agar shreds	15 grams
Liebig's meat extract	3 grams
Witte's peptone	10 grams
Lactose	10 grams
Distilled water	1 liter

The reaction of this medium was adjusted to one percent normal acid to phenolphthalein. The plates were incubated seven days: five days at 20° C. and two days at 37° C.

It should be understood that this method of counting the bacteria does not show the total number present. It was used because among the available methods of making such determinations this one seemed best suited to the problem.

PART I.—INFLUENCE SHOWN BY DIRECT EXAMINATION OF UTENSILS

Six experiments are recorded in this part of the study, five of them devoted to cans and one to bottles. The aim in these experiments was, first, to determine the number of bacteria in freshly washed but unsteamed cans and bottles; second, to determine whether bacteria increase in utensils that are washed and then kept for a period of time before being filled with milk; and third, to determine the source of these bacteria.

BACTERIA FOUND IN FRESHLY WASHED CANS

This experiment included a study of 170 cans that had been used in shipping sweet milk from the farm to the dairy. The cans reported upon in Tables 1, 2, and 3 came to Dairy A from three different farms, and those in Table 4 came to Dairy B from thirty-four different farms. In both dairies the cans were washed immediately after the milk was poured from them. The methods of washing followed in these two dairies and the method of determining the germ life remaining in the cans have already been described (page 219). The length of time intervening between the washing of the cans and the plating of the water with which they were rinsed varied from one-half to four hours.

That such rinsing did not remove all the bacteria from the utensils is self evident. In this experiment, therefore, an attempt was also made to determine approximately the accuracy of the method. For this purpose each can in Tables 1, 2, and 3 was rinsed more than once, and the relation between the number of bacteria removed by the first rinsing and that removed by subsequent rinsings was calculated. The cans in Table 1 were rinsed twice with 1,000 and 1,500 cc. of sterile water, respectively; those in Table 2 were rinsed four times with successive one-liter portions of sterile water; those in Table 3 were rinsed four times with successive two-liter portions of sterile water; and those in Table 4 were rinsed once with one liter of sterile water.

Calculations are also presented which show what the increase in the germ content of milk would have been had the total number of bacteria removed from each can been added to a can of milk.

The results of this experiment are significant in that the numbers of bacteria removed from the washed cans by rinsing them with a small quantity of sterile water were large and variable. More than one billion bacteria were removed from each of 39 of the 114 cans washed in Dairy A, and from each of 38 others the number was more than one hundred million. Even larger numbers were removed from the 56 cans washed in Dairy B; in which dairy, it will be recalled, the milk as it was received had a higher germ content than that received at Dairy A, a greater number of cans were washed in a smaller amount of water, and the cans were not rinsed after being washed. More than one billion bacteria were removed from each of 42 of the cans in this dairy, and in only 4 cans was the number smaller than one hundred million. The largest number removed from a single can in either dairy was 96,666,000,000, and the smallest was 5,981,000.

The influence of such large numbers of bacteria on the milk may be estimated approximately by calculating the increase in the germ content of a can of milk if these numbers were added to it. The two above cans with the maximum and minimum numbers were of ten- and eight-gallon capacity, respectively. If the minimum number, 5,981,000 bacteria, were added to eight gallons of milk, its germ content

TABLE 1.—NUMBER OF BACTERIA IN FRESHLY WASHED CANS, AS DETERMINED BY TWO SUCCESSIVE RINSINGS: DAIRY A

No. of can	Number of bacteria removed by each rinsing		Total number of bacteria removed	Increase in germ content of can of milk, per cc.	Percentage of bacteria removed by 1st rinsing
	Rinsed with 1,000 cc. of sterile water	Rinsed with 1,500 cc. of sterile water			
1	16 400 000	547 000	16 947 000	559	97
2	16 560 000	530 000	17 090 000	564	97
3	38 840 000	3 370 000	42 210 000	1 394	92
4	14 570 000	680 000	15 250 000	503	96
5	229 750 000	11 320 000	241 070 000	7 960	95
6	312 300 000	33 500 000	345 800 000	11 425	90
7	9 157 000 000	810 000 000	9 967 000 000	329 100	92
8	603 400 000	122 000 000	725 400 000	23 950	83
9	61 000 000	1 500 000	62 500 000	2 064	98
10	61 360 000	1 550 000	62 910 000	2 097	98
11	13 000 000 000	1 877 000 000	14 877 000 000	491 300	87
12	681 400 000	308 600 000	990 000 000	32 700	69
13	16 040 000	812 000	16 852 000	556	95
14	50 470 000	2 412 000	52 882 000	1 746	95
15	168 800 000	30 000 000	198 800 000	6 564	85
16	83 560 000	19 500 000	103 060 000	3 404	81
17	20 580 000 000	3 150 000 000	23 730 000 000	783 600	87
18	40 280 000	12 075 000	52 355 000	1 729	77
19	20 940 000	1 102 000	22 042 000	727	95
20	52 000 000	2 467 000	54 467 000	1 799	95
21	3 986 500 000	317 000 000	4 303 500 000	142 150	93
22	4 898 000 000	485 000 000	5 383 000 000	177 750	91
23	1 212 000 000	57 700 000	1 269 700 000	41 930	95
24	4 302 000 000	362 000 000	4 664 000 000	154 000	92
25	2 413 000 000	213 000 000	2 626 000 000	86 720	92
26	5 324 000 000	370 000 000	5 694 000 000	188 000	94
27	145 950 000	30 775 000	176 725 000	5 836	83
28	104 500 000	60 200 000	164 700 000	5 439	63
29	7 631 000 000	1 120 000 000	8 751 000 000	289 000	87
30	80 640 000	11 125 000	91 765 000	3 030	88
31	123 500 000	58 750 000	182 250 000	6 018	68
32	33 290 000	3 130 000	36 420 000	1 202	91

Table 2.—Number of Bacteria in Freshly Washed Cans, as Determined by Four Successive Rinsings with One Liter of Sterile Water: Dairy A

No. of can	Number of bacteria removed by—				Total number of bacteria removed	Increase in germ content of can of milk, per cc.	Percentage of bacteria removed by 1st rinsing
	1st rinsing	2d rinsing	3d rinsing	4th rinsing			
1	339 633 000	61 767 000	33 133 000	21 119 000	455 652 000	15 048	75
2	10 466 000	1 271 000	589 000	282 000	12 608 000	416	83
3	796 499 000	190 299 000	143 299 000	60 826 000	1 190 923 000	39 324	67
4	34 733 000	6 433 000	2 378 000	160 000	43 704 000	1 443	79
5	11 366 000	959 000	244 000	161 000	12 730 000	420	89
6	19 433 000	893 000	999 000	173 000	21 498 000	709	90
7	16 700 000	1 360 000	618 000	411 000	19 089 000	630	87
8	514 500 000	243 300 000	157 660 000	61 000 000	976 460 000	32 245	53
9	20 850 000	1 520 000	259 000	185 000	22 814 000	753	91
10	427 850 000	60 000 000	25 830 000	19 466 000	533 146 000	17 600	80
11	2 863 333 000	701 716 000	436 000 000	37 666 000	4 038 715 000	133 370	71
12	95 000 000	5 500 000	1 700 000	1 266 000	103 496 000	3 418	92
13	29 233 000	6 096 000	2 919 000	1 932 000	40 180 000	1 326	73
14	6 549 333 000	633 088 000	489 166 000	302 213 000	7 973 800 000	263 300	82
15	64 400 000	11 300 000	6 338 000	3 200 000	85 238 000	2 814	78
16	86 150 000	22 400 000	10 900 000	6 516 000	125 966 000	4 159	68
17	2 800 000	1 800 000	989 000	382 000	5 981 000	197	47
18	18 800 000	3 190 000	2 541 000	1 246 000	25 777 000	851	73
19	2 370 000 000	1 216 000 000	706 100 000	44 244 000	4 336 344 000	143 170	55
20	668 000 000	199 600 000	95 150 000	50 600 000	1 013 350 000	33 450	66
21	88 000 000	15 150 000	5 890 000	1 244 000	110 284 000	3 639	80
22	175 000 000	26 900 000	18 560 000	14 195 000	234 655 000	7 747	75
23	368 000 000	83 000 000	49 200 000	27 900 000	528 100 000	17 430	70
24	3 620 000 000	890 000 000	352 300 000	20 200 000	4 882 500 000	161 200	74
25	2 170 000 000	416 000 000	304 600 000	342 930 000	3 233 530 000	106 800	67
26	1 610 000 000	171 000 000	82 000 000	37 000 000	1 900 000 000	62 740	85
27	97 450 000	9 475 000	10 870 000	5 570 000	123 365 000	4 075	79
28	20 133 000 000	2 843 000 000	886 600 000	895 000 000	27 757 000 000	916 600	73
29	403 500 000	59 850 000	52 800 000	27 900 000	544 050 000	17 965	74
30	3 590 000 000	715 000 000	174 700 000	150 100 000	4 629 800 000	152 990	78
31	525 500 000	51 500 000	28 400 000	22 100 000	627 500 000	20 740	84
32	159 500 000	14 100 000	5 120 000	3 040 000	181 760 000	6 002	88
33	222 000 000	14 400 000	6 825 000	3 800 000	247 025 000	8 156	90
34	7 650 000 000	2 720 000 000	314 200 000	410 700 000	11 094 900 000	366 400	69
35	1 330 000 000	134 350 000	49 700 000	39 800 000	1 553 850 000	51 320	86
36	1 557 000 000	125 500 000	91 900 000	39 933 000	1 814 333 000	59 900	86
37	222 000 000	15 000 000	6 485 000	3 700 000	247 185 000	8 161	90
38	32 930 000 000	918 000 000	377 300 000	36 888 000	34 262 180 000	1 131 000	96
39	109 333 000	98 667 000	61 600 000	57 533 000	327 133 000	10 800	33
40	561 333 000	171 667 000	73 400 000	554 000	806 954 000	26 710	69
41	78 133 000	23 983 000	11 750 000	6 010 000	119 876 000	3 958	65
42	2 150 667 000	431 333 000	201 000 000	125 000 000	2 908 000 000	96 040	74
43	154 000 000	78 867 000	43 467 000	28 866 000	305 200 000	10 080	51
44	216 000 000	70 667 000	19 633 000	21 007 000	327 367 000	10 810	66
45	528 666 000	47 044 000	28 367 000	29 833 000	633 910 000	20 930	83
46	350 000 000	77 933 000	35 000 000	30 733 000	493 666 000	16 300	71
47	1 036 667 000	286 667 000	119 600 000	84 133 000	1 427 007 000	47 120	73
48	1 710 000 000	612 007 000	219 033 000	180 750 000	2 722 450 000	89 800	63
49	1 935 333 000	461 333 000	209 533 000	158 667 000	2 764 866 000	91 300	70
50	2 720 000 000	756 000 000	213 200 000	272 000 000	3 961 200 000	130 800	69

would be increased by 197 bacteria per cubic centimeter. If 96,666,000,000 bacteria, the maximum number found in a single can, were added to ten gallons of milk, its germ content would be increased by 2,557,000 bacteria per cubic centimeter. If all the bacteria removed from the 32 eight-gallon cans listed in Table 1 were added to 256 gallons of milk (the total capacity of the cans), its germ content would be increased by 87,657 bacteria per cubic centimeter. Corresponding calculations for Tables 2, 3, and 4 would show an average increase in the germ content of the milk, of 87,059, 47,863, and 291,790 bacteria, respectively.

Of the 170 cans recorded in these tables, 54, or 31.8 percent, would have added more than 100,000 bacteria per cubic centimeter of milk;

TABLE 3.—NUMBER OF BACTERIA IN FRESHLY WASHED CANS, AS DETERMINED BY FOUR SUCCESSIVE RINSINGS WITH TWO LITERS OF STERILE WATER: DAIRY A

No. of can	Number of bacteria removed by—				Total number of bacteria removed	Increase in germ content of can of milk, per cc.	Percentage of bacteria removed by 1st rinsing
	1st rinsing	2d rinsing	3d rinsing	4th rinsing			
1	35 334 000	2 466 000	1 466 000	1 066 000	40 332 000	1 331	87
2	122 666 000	18 866 000	17 000 000	12 068 000	170 600 000	5 634	72
3	374 666 000	192 666 000	109 334 000	104 666 000	781 332 000	25 800	48
4	300 000 000	87 000 000	33 466 000	33 614 000	454 200 000	14 990	66
5	28 666 000	4 666 000	2 666 000	1 066 000	37 064 000	1 224	77
6	5 146 666 000	1 888 000 000	1 237 334 000	858 666 000	9 130 666 000	301 500	56
7	40 666 000	1 134 000	600 000	334 000	42 534 000	1 404	95
8	111 000 000	13 666 000	7 868 000	4 634 000	137 168 000	4 530	81
9	25 334 000	2 400 000	934 000	932 000	39 600 000	1 307	85
10	37 666 000	5 000 000	2 000 000	1 800 000	45 466 000	1 502	80
11	1 746 666 000	320 000 000	233 334 000	148 666 000	2 448 666 000	80 840	71
12	1 016 666 000	238 666 000	263 334 000	138 968 000	1 657 634 000	54 720	61
13	594 666 000	282 000 000	179 600 000	151 066 000	1 207 332 000	39 880	49
14	80 666 000	8 200 000	2 866 000	2 068 000	93 800 000	3 098	86
15	54 666 000	1 200 000	1 532 000	466 000	57 864 000	1 910	94
16	5 310 000 000	997 000 000	536 000 000	414 666 000	7 357 666 000	242 960	73
17	46 000 000	2 934 000	600 000	532 000	50 066 000	1 652	92
18	234 000 000	4 414 000	3 800 000	934 000	293 268 000	9 685	96
19	4 320 000 000	714 000 000	582 000 000	351 334 000	5 977 334 000	197 080	72
20	13 334 000	1 800 000	1 266 000	400 000	16 800 000	554	79
21	42 666 000	2 344 000	724 000	466 000	46 200 000	1 524	92
22	78 000 000	7 866 000	3 266 000	2 334 000	91 466 000	3 020	85
23	3 186 666 000	574 000 000	466 000 000	354 000 000	4 780 666 000	157 840	71
24	78 666 000	6 800 000	4 400 000	2 734 000	92 600 000	3 058	85
25	2 500 000 000	462 666 000	327 000 000	194 000 000	3 483 666 000	115 020	72
26	766 666 000	186 000 000	204 134 000	45 600 000	1 203 000 000	39 740	64
27	55 000 000	4 534 000	2 134 000	2 400 000	64 068 000	2 116	86
28	322 666 000	41 334 000	18 000 000	20 066 000	402 066 000	13 274	80
29	637 000 000	128 814 000	64 034 000	58 168 000	888 136 000	29 320	72
30	170 666 000	8 400 000	10 600 000	3 600 000	193 266 000	6 384	88
31	78 666 000	7 066 000	1 800 000	1 800 000	89 332 000	2 950	88
32	3 226 666 000	928 666 000	575 334 000	293 334 000	5 004 000 000	165 220	64

54 would have added more than 10,000 and less than 100,000 bacteria; and 62 cans, or 36.4 percent, would have added less than 10,000.

The data in Tables 1, 2, and 3 demonstrate that when milk cans are rinsed more than once, the first rinsing always removes a larger number of bacteria than any subsequent single rinsing. When four rinsings were made in succession, in 78 out of 82 cases the first rinsing alone removed more bacteria than all three subsequent rinsings. The data also indicate, with only fifteen exceptions, that any one of the consecutive rinsings of a can removes more bacteria than any subsequent rinsing.

If the total number of bacteria removed from each can by all the rinsings is taken as 100 percent, the calculations will show that from 110 of the 114 cans the first rinsing removed more than 50 percent of the bacteria. The highest percentage removed by the first rinsing was 97, and the lowest was 33. The average percentage removed by the first rinsing of the cans rinsed only twice, once with 1,000 cc. and once with 1,500 cc. of water (Table 1), was 89; for the cans rinsed

TABLE 4.—NUMBER OF BACTERIA IN FRESHLY WASHED CANS, AS DETERMINED BY ONE RINSING WITH ONE LITER OF STERILE WATER: DAIRY B

No. of can	Capacity, gal.	Number of bacteria removed by rinsing	Increase in germ content of can of milk, per cc.	No. of can	Capacity, gal.	Number of bacteria removed by rinsing	Increase in germ content of can of milk, per cc.
1	5	7 360 000 000	389 400	29	10	7 133 000 000	188 700
2	8	1 960 000 000	64 730	30	5	30 000 000 000	1 587 300
3	8	490 000 000	16 180	31	10	17 466 000 000	462 080
4	10	3 680 000 000	97 350	32	5	1 853 000 000	98 040
5	5	1 430 000 000	75 660	33	10	96 666 000 000	2 557 000
6	8	1 390 000 000	45 900	34	8	886 000 000	29 260
7	8	1 590 000 000	52 500	35	5	4 366 000 000	231 000
8	5	5 690 000 000	301 050	36	5	806 000 000	42 640
9	5	222 000 000	11 740	37	8	60 000 000	1 981
10	8	2 310 000 000	76 290	38	5	90 000 000	4 760
11	8	2 940 000 000	97 100	39	8	2 240 000 000	73 970
12	8	11 070 000 000	353 360	40	5	2 486 000 000	131 540
13	10	8 550 000 000	226 180	41	8	8 883 000 000	293 360
14	8	38 670 000 000	1 277 000	42	8	190 000 000	62 740
15	8	8 730 000 000	288 300	43	5	1 500 000 000	79 360
16	5	1 596 000 000	84 450	44	5	2 690 000 000	142 330
17	10	330 000 000	8 730	45	8	143 000 000	4 722
18	8	7 446 000 000	245 900	46	8	2 533 000 000	83 650
19	5	8 860 000 000	468 800	47	10	14 000 000 000	370 300
20	8	8 566 000 000	282 880	48	8	6 200 000 000	204 740
21	5	736 000 000	38 940	49	5	4 186 000 000	221 480
22	5	250 000 000	13 230	50	8	18 830 000 000	621 800
23	5	256 000 000	13 540	51	10	9 133 000 000	241 600
24	5	2 560 000 000	135 450	52	8	19 666 000 000	649 400
25	5	16 360 000 000	865 600	53	10	11 233 000 000	297 150
26	5	83 000 000	4 390	54	8	66 000 000	2 179
27	5	2 106 000 000	109 000	55	8	3 100 000 000	102 370
28	5	23 660 000 000	1 251 800	56	8	3 160 000 000	104 350

four times with one liter of water (Table 2), it was 74.6; and for the cans rinsed four times with two liters of water (Table 3), it was 77.

The results of these observations on 170 cans suggest that milk cans when washed in the ordinary manner contain sufficient germ life to heavily inoculate the milk later placed in them. The results of successive rinsings with sterile water suggest that while the germ life removed by the first rinsing amounts to a considerable fraction of the germ life in the can, it is by no means the entire germ life present. Accordingly, the germ content as determined in this manner is distinctly below the true number of bacteria actually present in the utensil under investigation.

BACTERIA FOUND IN CANS THIRTY HOURS AFTER BEING WASHED

In the preceding experiment it was shown that freshly washed cans invariably harbored large numbers of bacteria. In dairy practice the utensils, however, are not commonly used for milk immediately after they are washed. This is especially true of cans in which milk is shipped from the farm to the dairy. Such cans are washed and usually steamed at the dairy; then covered with the lids and returned to the farm, where they are frequently used for milk without any further treatment. At times, one or even two days will elapse between the washing of the cans and their use.

This experiment was designed, therefore, to determine the germ life in cans at the time they would ordinarily be used. The 160 eight-gallon cans examined were washed in Dairy A. One hundred of these were steamed, while sixty were left unsteamed.

The steaming consisted of holding each can over a jet of steam at 15 pounds pressure for 25 seconds. The pressure of the steam was measured by a gage placed between the valve and the jet opening. Other experiments upon steaming cans in this manner showed that if cans so treated were filled with milk immediately afterward, they rarely added more than 2 bacteria per cubic centimeter to the milk. Fifty of the steamed cans and fifty of those not steamed were inverted on a rack with the lids off. The other fifty steamed cans and the ten not steamed were closed immediately after washing. All the cans were then kept thirty hours in a room having a humidity of 40 percent and a temperature of 60° to 70°F. The number of bacteria found in each can is shown in Table 5.

The fifty cans that were washed, steamed, and then held thirty hours uncovered and inverted on a rack were dry and free from bad odor. The number of bacteria found in them was small in all cases. Only 3 of the fifty cans had more than one million bacteria and 36 of them had less than 100,000. If the bacteria found in these fifty cans were added to 400 gallons of milk, the germ content of this

TABLE 5.—NUMBER OF BACTERIA IN STEAMED AND IN UNSTEAMED CANS HELD THIRTY HOURS AFTER TREATMENT: DAIRY A

(As determined by rinsing with one liter of sterile water)

Steamed cans held 30 hours				Unsteamed cans held 30 hours			
Uncovered and inverted on a rack		Covered with their lids		Uncovered and inverted on a rack		Covered with their lids	
No. of can	No. of bacteria	No. of can	No. of bacteria	No. of can	No. of bacteria	No. of can	No. of bacteria
1	20 000	51	10 000	101	164 000 000	151	6 910 000 000
2	20 000	52	60 000	102	148 000 000	152	5 520 000 000
3	20 000	53	66 000 000	103	6 000 000	153	4 150 000 000
4	30 000	54	6 800 000	104	170 000 000	154	4 300 000 000
5	30 000	55	3 260 000	105	190 000 000	155	6 000 000 000
6	20 000	56	15 000 000	106	17 000 000 000	156	2 100 000 000
7	40 000	57	10 600 000	107	7 300 000 000	157	1 400 000 000
8	10 000	58	11 600 000	108	44 000 000	158	6 250 000 000
9	20 000	59	21 300 000	109	3 000 000	159	1 900 000 000
10	240 000	60	220 000	110	22 000 000	160	450 000 000
11	100 000	61	60 000 000	111	10 100 000 000		
12	290 000	62	210 000	112	1 000 000		
13	700 000	63	110 000	113	135 000 000		
14	40 000	64	30 000	114	1 000 000		
15	60 000	65	213 000 000	115	303 000 000		
16	60 000	66	39 000 000	116	76 000 000		
17	600 000	67	550 000	117	8 000 000		
18	1 450 000	68	48 000 000	118	9 000 000		
19	50 000	69	14 100 000	119	94 000 000		
20	430 000	70	2 180 000	120	59 000 000		
21	90 000	71	2 260 000	121	14 000 000		
22	30 000	72	4 800 000	122	3 000 000		
23	30 000	73	210 000	123	42 000 000		
24	50 000	74	110 000 000	124	22 000 000		
25	330 000	75	14 500 000	125	278 000 000		
26	150 000	76	210 000	126	4 700 000 000		
27	90 000	77	35 500 000	127	48 000 000		
28	30 000	78	7 000 000	128	2 000 000		
29	80 000	79	1 310 000	129	10 000 000		
30	30 000	80	35 000 000	130	21 000 000		
31	30 000	81	130 000	131	8 000 000		
32	60 000	82	4 380 000	132	1 000 000		
33	50 000	83	78 000 000	133	1 000 000		
34	90 000	84	240 000	134	17 000 000		
35	60 000	85	12 500 000	135	1 000 000		
36	20 000	86	89 000 000	136	48 000 000		
37	2 720 000	87	43 000 000	137	1 000 000		
38	30 000	88	1 190 000 000	138	3 000 000		
39	120 000	89	33 000 000	139	1 000 000		
40	30 000	90	67 000 000	140	3 000 000		
41	3 700 000	91	240 000	141	2 000 000		
42	100 000	92	50 000 000	142	2 000 000		
43	50 000	93	270 000 000	143	43 000 000		
44	20 000	94	240 000	144	2 000 000		

TABLE 5.—*Concluded*

Steamed cans held 30 hours				Unsteamed cans held 30 hours			
Uncovered and inverted on a rack		Covered with their lids		Uncovered and inverted on a rack		Covered with their lids	
No. of can	No. of bacteria	No. of can	No. of bacteria	No. of can	No. of bacteria	No. of can	No. of bacteria
45	30 000	95	149 000 000	145	5 000 000		
46	40 000	96	710 000	146	2 000 000		
47	330 000	97	590 000	147	2 000 000		
48	80 000	98	16 000 000	148	3 000 000		
49	60 000	99	550 000	149	5 000 000		
50	30 000	100	22 000 000	150	170 000		
Average no. of bacteria per can	255,800		54 988 000		822 463 400		3 898 000 000
Average no. of bacteria per cc. in can of milk	8		1 816		27 164		128 730

amount of milk would be increased by 8 bacteria per cubic centimeter. Whether any bacterial growth took place in these cans during the thirty hours is not certain, but the results show that cans so treated have a negligible effect upon the germ content of milk.

The fifty cans that were washed, steamed, and then held thirty hours with the lids on, were still wet and most of them had a more or less pronounced odor. These cans had a much larger number of bacteria than those steamed, uncovered, and inverted. Only 3 of the fifty cans had less than 100,000 bacteria, and in 34 the number was over one million. If the bacteria found in these fifty eight-gallon cans were added to 400 gallons of milk, its germ content would be increased by 1,816 bacteria per cubic centimeter.

The fifty cans that were washed but not steamed and were then held thirty hours uncovered and inverted, were dry. None of the cans had a bad odor, altho most of them were not what is called "sweet smelling." The number of bacteria in them was much larger than in the cans steamed and inverted. Only one of the fifty cans had less than one million bacteria, in 24 of them the numbers of bacteria were between one million and ten millions, and 4 cans had over a billion bacteria each. If the bacteria found in all these cans were added to 400 gallons of milk, its germ content would be increased by 27,164 bacteria per cubic centimeter. It is, however, to be observed that this average number does not give an accurate idea of the condition of these cans since the total number of bacteria found in the fifty cans was 41,123,170,000, and of this number 39,100,000,000 were contributed by only 4 cans and 2,023,170,000 by the remaining 46 cans. The germ content of milk in these 46 cans would have averaged only 1,336 bacteria per cubic centimeter. The destructive effect of the drying of the cans upon the germ life in them is evident from a comparison of these results with those obtained from the freshly washed cans reported in Tables 1, 2, and 3.

The ten cans that were washed but not steamed and then were covered and held thirty hours had in all cases a decidedly bad odor and they also contained large numbers of bacteria. Nine of the ten cans showed over a billion bacteria each. If the total number of bacteria found in these ten eight-gallon cans were added to 80 gallons of milk, its germ content would have been increased by 128,730 bacteria per cubic centimeter.

It is evident from these results that pronounced bacterial growth took place in the cans that were covered and allowed to stand for thirty hours. Bacterial growth in general is conditioned by three factors: temperature, food, and moisture. All the cans in this experiment were held at the same temperature and were washed in the same dairy by the same operator, so that the principal difference between the covered and the uncovered cans was the persistance of moisture in the covered cans. These results point to the conclusion that it is very difficult to wash cans so that no bacterial food is left in them, and if the cans are then covered without being dried, and are allowed to stand for a period of time, the bacteria in them increase to large numbers.

BACTERIA FOUND IN CANS WASHED AND RETURNED TO THE FARM

This experiment was designed to measure the germ life in cans that were washed and returned to several dairy farms ready for use. In order to maintain the usual conditions in this dairy (Dairy A), no interference was made in any of the usual operations and the men doing the work were not aware of the experiment. No record could be obtained of the exact treatment of the individual cans, but in general each can was washed, rinsed, steamed over a jet, and covered with a lid. Casual observations indicated that the steaming of the cans varied from five to twenty seconds per can.

The treatment of the cans at the farms was not uniform. At times they were inverted on a rack, with lids off, and at other times they were not opened until used. The time intervening between the washing of the cans and their use varied from six to forty hours.

Just before the cans were used for milk they were rinsed with one liter of sterile water and the germ content of this water was determined. Table 6 presents the results of the examination of 91 cans.

As in the other experiments, the numbers of bacteria found in these cans were varied and in some cases large. Can 43, for example, showed 80,000 bacteria, and Can 66 showed 30,830,000,000 bacteria. Of the

TABLE 6.—NUMBER OF BACTERIA IN CANS AFTER THEY WERE WASHED AND STEAMED IN THE DAIRY AND RETURNED TO THE FARM: DAIRY A

(As determined by rinsing with one liter of sterile water)

No. of can	Number of bacteria in cans	Increase in germ content of can of milk, per cc.	No. of can	Number of bacteria in cans	Increase in germ content of can of milk, per cc.
1	56 950 000	1 880	47	133 833 000	4 420
2	636 500 000	21 020	48	47 750 000	1 577
3	388 000 000	12 870	49	149 000 000	4 920
4	1 400 000	46	50	675 000 000	22 290
5	1 400 000	46	51	10 950 000 000	361 600
6	1 505 000 000	49 700	52	995 000 000	32 860
7	107 500 000	3 555	53	83 100 000	2 744
8	4 550 000	150	54	520 000 000	17 170
9	74 750 000	2 468	55	16 720 000	552
10	42 700 000	1 387	56	168 700 000	5 570
11	26 400 000	871	57	19 570 000	646
12	21 300 000	703	58	26 500 000	875
13	11 375 000	375	59	90 640 000	2 993
14	80 650 000	2 633	60	988 000	30
15	37 000 000	1 222	61	39 900 000	1 317
16	162 025 000	5 320	62	1 187 000 000	39 190
17	37 225 000	1 229	63	1 900 000	62
18	55 075 000	1 819	64	1 949 000 000	64 340
19	82 000 000	2 708	65	581 000 000	19 200
20	24 975 000	825	66	30 830 000 000	1 018 000
21	37 325 000	1 233	67	30 280 000	1 000
22	488 000 000	16 110	68	82 900 000	2 737
23	400 000 000	13 210	69	41 025 000	1 355
24	20 500 000	677	70	68 850 000	2 273
25	36 000 000	1 187	71	51 960 000	1 716
26	102 000 000	3 368	72	62 900 000	2 077
27	22 000 000	726	73	125 350 000	4 140
28	17 000 000	561	74	56 210 000	1 856
29	2 045 000 000	67 530	75	80 030 000	2 642
30	382 000 000	12 610	76	40 000 000	1 340
31	63 500 000	2 097	77	112 700 000	3 722
32	36 000 000	1 189	78	59 050 000	1 950
33	83 000 000	2 742	79	506 700 000	16 730
34	5 500 000	187	80	79 070 000	2 611
35	4 500 000	148	81	28 820 000	951
36	354 500 000	11 700	82	1 698 000 000	56 070
37	42 000 000	1 387	83	42 730 000	1 411
38	3 270 000 000	108 000	84	351 750 000	11 611
39	200 000	7	85	17 320 000	572
40	18 766 000	620	86	46 270 000	1 527
41	22 750 000	751	87	173 750 000	5 734
42	75 166 000	2 482	88	80 060 000	2 644
43	80 000	3	89	432 000 000	14 260
44	59 425 000	1 963	90	1 015 000 000	33 530
45	85 300 000	2 817	91	6 530 000	215
46	44 716 000	1 476			

91 cans examined, 3, or 3.3 percent, showed less than one million bacteria; 57 cans, or 62.6 percent, showed between one million and one hundred million bacteria; and 31, or 34.1 percent, showed over one hundred million bacteria.

If the number of bacteria found in Can 43 were added to eight gallons of milk (the capacity of the can), the germ content of the milk would be increased by 3 bacteria per cubic centimeter; in the case of Can 66 it would be increased by 1,018,000 bacteria. If all the bacteria found in the 91 cans were added to 728 gallons of milk (the total capacity of these cans), the germ content of this milk would be increased by 23,523 bacteria per cubic centimeter.

These cans were inspected prior to the bacteriological examination and were found to be free from any dirt and in most cases dry. It is impossible to state with certainty whether they were in a better or in a worse condition than the cans used for milk on farms in general. However, from somewhat extensive inspection of cans on a large number of farms and in dairies, the authors are of the opinion that these 91 cans were cleaner and in a better condition than the average can used for milk.

SOURCES OF BACTERIA IN WASHED CANS

The results already presented show that there are large numbers of bacteria in freshly washed cans, and that in some cans the numbers are extremely large. Two of the possible sources of these large numbers of bacteria are the milk that was previously in the can and the water in which the can was washed.

Milk as the Source of the Bacteria

In this experiment samples for bacteriological study were taken from the milk of each of 153 cans. The cans were then emptied and washed and the number of bacteria in them was determined. The results of these examinations are given in Tables 7, 8, and 9.

An examination of these tables shows that the germ content of the milk in the cans, as it arrived at the dairies, was much higher in Dairy B than in Dairy A. The number of bacteria in the cans after they were emptied and washed was likewise higher in Dairy B than in Dairy A. When, however, the comparison is confined to the individual cans in the same dairy, the relation between the germ content of the milk of a given can and the number of bacteria found in the can after it was emptied and washed, is not so evident. In a few cases, as is seen especially in the results from the cans numbering 85 to 106, a certain relation does exist, but in most cases it is not discernable.

How many of the bacteria found in a given washed can came from the milk held by the can previous to washing would naturally depend on the germ content of the milk and also on the amount of the milk left in the can after it was washed. It is self evident that after the

TABLE 7.—GERM CONTENT OF MILK IN THE CANS, AND NUMBER OF BACTERIA IN THE CANS AFTER THEY WERE WASHED
(Bacteria in cans determined by rinsing with one liter of sterile water)

No. of can	Germ content of milk in cans, per cc.	No. of bacteria in the can after being washed	No. of can	Germ content of milk in cans, per cc.	No. of bacteria in the can after being washed
		Dairy A			
1	380 000	214 000 000	21	1 400	5 900 000
2	342 000	60 000 000	22	1 100	5 900 000
3	298 000	2 000 000	23	1 000	7 400 000
4	175 000	9 000 000	24	21 200	2 000 000
5	51 000	2 000 000	25	10 000	700 000
6	51 000	1 000 000	26	8 800	500 000
7	48 000	2 000 000	27	7 200	700 000
8	13 000	2 000 000	28	3 600	2 000 000
9	4 900	2 000 000	29	2 300	2 600 000
10	5 300	5 000 000	30	1 300	800 000
11	3 400	15 000 000	31	1 100	4 900 000
12	213 000	9 000 000	32	59 800	3 200 000
13	178 000	8 900 000	33	40 300	3 600 000
14	176 000	9 100 000	34	23 600	363 000 000
15	152 000	6 800 000	35	16 700	9 100 000
16	130 000	3 400 000	36	11 400	3 300 000
17	18 000	6 300 000	37	3 600	7 000 000
18	7 400	4 400 000	38	1 900	3 200 000
19	4 000	14 300 000	39	1 800	4 500 000
20	2 500	10 100 000	40	1 000	3 800 000
		Dairy B			
41	101 300 000	113 670 000 000	74	40 000	430 000 000
42	52 000 000	49 330 000 000	75	2 210 000	1 690 000 000
43	40 800 000	4 100 000 000	76	300 000	4 440 000 000
44	33 500 000	13 400 000 000	77	5 520 000	30 400 000 000
45	18 170 000	2 870 000 000	78	350 000	18 650 000 000
46	18 000 000	6 060 000 000	79	10 830 000	5 670 000 000
47	13 200 000	7 970 000 000	80	14 500 000	8 400 000 000
48	9 370 000	930 000 000	81	2 750 000	70 660 000 000
49	6 920 000	4 900 000 000	82	1 390 000	104 330 000 000
50	6 600 000	2 220 000 000	83	290 000	21 800 000 000
51	5 460 000	8 000 000 000	84	9 500 000	720 000 000
52	5 270 000	330 000 000	85	10 000	140 000 000
53	4 530 000	51 330 000 000	86	550 000	1 200 000 000
54	4 490 000	1 660 000 000	87	1 970 000	26 970 000 000
55	3 950 000	3 160 000 000	88	710 000	4 680 000 000
56	3 400 000	40 000 000 000	89	350 000	12 600 000 000
57	3 000 000	690 000 000	90	20 000	3 890 000 000
58	2 960 000	62 060 000 000	91	650 000	18 920 000 000
59	2 460 000	47 000 000 000	92	10 000	200 000 000
60	2 010 000	9 470 000 000	93	1 500 000	19 070 000 000
61	1 990 000	7 600 000 000	94	220 000	3 460 000 000
62	1 820 000	650 000 000	95	40 000	130 000 000
63	1 000 000	5 270 000 000	96	900 000	26 240 000 000
64	910 000	9 400 000 000	97	510 000	5 080 000 000
65	800 000	110 000 000	98	170 000	2 080 000 000
66	620 000	43 000 000 000	99	10 000	190 000 000
67	510 000	4 300 000 000	100	130 000	1 580 000 000
68	340 000	2 130 000 000	101	11 500 000	65 000 000 000
69	320 000	11 470 000 000	102	2 060 000	21 660 000 000
70	230 000	5 270 000 000	103	60 000	650 000 000
71	160 000	3 070 000 000	104	420 000	16 400 000 000
72	70 000	920 000 000	105	2 000 000	40 330 000 000
73	70 000	250 000 000	106	40 000	270 000 000

can is emptied and washed, the amount of the milk still adhering to the walls of the can is extremely small.

That the milk held by a can previous to washing was not the principal source of the bacteria in the washed cans in cases where the number of bacteria was large, may be shown by calculating the amount of the milk that would have been necessary to have supplied the number of bacteria found in the washed cans. Cans 65 and 66 may be taken for this calculation. These two cans were washed in succession, within one minute of each other, in the same wash water. The germ content of the milk held by Can 65 was 800,000 bacteria per cubic centimeter, and the number of bacteria in this can after it was washed was 110,000,000. It would have required 137 cc. of the milk to have supplied the number of bacteria found in the can after it was washed. The germ content of the milk in Can 66 was 620,000 bacteria per cubic centimeter, and after the can was washed the number of bacteria found in it was 43,000,000,000. In this case it would have required 69,355 cc. (about 18 gallons) of the milk to have supplied this number of bacteria.

It is seen from this experiment, therefore, that in dairies which receive milk with high germ content, the cans after being washed, and if not steamed, will have correspondingly large numbers of bacteria. On the other hand, the large numbers of bacteria in some cans after they are washed in the same dairy and in the same lot of wash water, must have some source other than the milk.

Wash Water as a Source of Bacteria

When milk is poured from a can, a small amount of it always adheres to the inner walls of the can. In the process of washing, these traces of milk are transferred to the wash water. It is evident that the germ content of the wash water may become very high if the milk was heavily seeded with bacteria, if the cans are dirty, or if a large number of cans are washed in the same lot of wash water. This experiment was therefore undertaken to determine the influence of the wash water on the number of bacteria in the washed cans.

All the cans reported in Table 8 were washed in one lot of wash water, and the same was true of those listed in Table 9. In Tables 10 and 11 a fresh lot of water was used for every set of cans, each set including from five to nine cans.

In Table 8 the wash water contained one percent of sodium-carbonate washing powder. In Table 9 the wash water contained no washing powder of any kind. In Table 10 each set of cans was washed first in one-percent washing-powder solution and, without using these cans for milk after this washing, they were washed again thirty minutes later but only in plain water. In Table 11 the cans were treated exactly as in Table 10 except that the first washing was done in plain water and the second washing in one-percent solution of washing powder.

In Tables 8 and 9 the samples for bacteriological study were taken from the milk of each can just before the cans were emptied and washed. The samples from the wash water were taken from the vat: first, at the beginning of washing; second, at certain intervals during the washing; and third, after all the cans were washed. In Tables 10 and 11, the milk samples were omitted, and the samples from the wash water in the vat were taken at the beginning and at the end of the washing of each set of cans.

TABLE 8.—GERM CONTENT OF MILK, OF WASH WATER, AND OF WASHED CANS
(Cans washed in 25 gallons of water, *with* washing powder: Dairy B)

No. of can	Germ content of milk in cans, per cc.	Bacteria removed from washed cans by one liter of rinse water	Germ content of wash water, per cc.
Before washing			100 000
1	2 210 000	1 690 000 000	
2	300 000	4 440 000 000	
3	5 520 000	30 400 000 000	
4	350 000	18 650 000 000	
5	10 830 000	5 670 000 000	
6	14 500 000	8 400 000 000	
7	2 750 000	70 660 000 000	
8	1 390 000	104 330 000 000	
9	290 000	21 800 000 000	
10	9 500 000	720 000 000	
11	10 000	140 000 000	
12	550 000	1 200 000 000	
After 12 cans were washed			3 210 000
13	1 970 000	26 970 000 000	
14	710 000	4 680 000 000	
15	350 000	12 000 000 000	
16	20 000	3 890 000 000	
17	650 000	18 920 000 000	
18	10 000	200 000 000	
19	1 500 000	19 070 000 000	
20	220 000	3 460 000 000	
21	40 000	130 000 000	
22	900 000	26 240 000 000	
After 22 cans were washed			3 420 000
23	510 000	5 080 000 000	
24	170 000	2 080 000 000	
25	10 000	190 000 000	
26	130 000	1 580 000 000	
27	11 500 000	65 000 000 000	
28	2 060 000	21 660 000 000	
29	60 000	650 000 000	
30	420 000	16 400 000 000	
31	2 000 000	40 330 000 000	
32	40 000	270 000 000	
After 32 cans were washed			5 100 000

After each can was washed it was allowed to stand twenty to thirty minutes; then one liter of sterile water was poured in and after thoro shaking, the germ content of this water was determined. In Tables 10 and 11 each can was washed twice in succession and the number of bacteria determined after each washing.

All the cans in Tables 8 and 9, those in Table 10 numbering 21 to 43, and those in Table 11 numbering 27 to 44 came from Dairy B. The remaining cans in Tables 10 and 11 came from Dairy A. For the purpose of this experiment, however, the usual methods of washing followed in these dairies were discarded and the cans in both dairies were washed in the same way. About 25 gallons of warm water was run into the vat, and when washing powder was used, one percent of it was added to the water. Each can was placed in the water, scrubbed with a brush, and then inverted on a rack for about six seconds to drain. None of the cans in either dairy were rinsed with plain water after being washed.

The germ content of the water supply in these dairies varied from 100 to 2,000 bacteria per cubic centimeter. It will be noticed from the above tables that when the water was run into the vat preparatory to being used for washing the cans, its germ content invariably increased. For example, in Table 8 before any cans were washed in the water the germ content was 100,000 bacteria per cubic centimeter. This increase was apparently due to the bacteria present on the inner surface of the vat.

TABLE 9.—GERM CONTENT OF MILK, OF WASH WATER, AND OF WASHED CANS
(Cans washed in 25 gallons of water, *without* washing powder: Dairy B)

No. of can	Germ content of milk in cans, per cc.	Bacteria removed from washed cans by one liter of rinse water	Germ content of wash water, per cc.
Before any cans were washed			155 000
33	3 060 000	480 000 000	
34	520 000	1 900 000 000	
35	130 000	1 180 000 000	
36	1 390 000	170 000 000	
37	1 870 000	8 750 000 000	
38	105 000 000	10 970 000 000	
39	640 000	820 000 000	
40	11 600 000	710 000 000	
41	940 000	50 000 000	
After 9 cans were washed			412 000
42	80 000	720 000 000	
43	80 000	490 000 000	
44	900 000	1 170 000 000	
45	830 000	10 000 000	
46	50 000	280 000 000	
47	6 300 000	14 690 000 000	
After 15 cans were washed			457 000

TABLE 10.—GERM CONTENT OF WASH WATER AND OF CANS WASHED TWICE IN SUCCESSION; FIRST IN WASHING-POWDER SOLUTION, THEN IN PLAIN WATER

(New lot of 25 gallons of water used for every 5 to 9 cans)

No. of can	First washing—washing powder		Second washing—plain water	
	Bacteria removed from washed cans by one liter of rinse water	Germ content of wash water, per cc.	Bacteria removed from washed cans by one liter of rinse water	Germ content of wash water, per cc.
		Dairy A		
Before washing		500		15 400
1	7 000 000		500 000	
2	24 000 000		400 000	
3	17 000 000		100 000	
4	1 000 000		100 000	
5	3 000 000			
After 5 cans were washed		14 200		44 400
Before washing		28 000		5 600
6	2 000 000		400 000	
7	3 000 000		400 000	
8	3 000 000		300 000	
9	2 000 000		900 000	
10	2 000 000		600 000	
11	2 000 000		500 000	
12	2 000 000		900 000	
13	47 000 000		10 600 000	
14	2 000 000		600 000	
After 9 cans were washed		88 000		28 000
Before washing		21 800		7 500
15	500 000		490 000	
16	700 000		600 000	
17	600 000		900 000	
18	700 000		410 000	
19	1 600 000		640 000	
20	700 000		620 000	
After 6 cans were washed		40 000		47 000
		Dairy B		
Before washing		28 000		17 000
21	190 000 000		30 900 000	
22	100 000 000		20 100 000	
23	3 190 000 000		723 000 000	
24	10 400 000 000		787 000 000	
25	240 000 000		14 600 000	
After 5 cans were washed		20 000 000		1 400 000
Before washing		30 000		7 000
26	10 000 000		100 000	
27	60 000 000		2 600 000	
28	60 000 000		2 300 000	
29	160 000 000		3 800 000	
30	1 450 000 000		30 800 000	
After 5 cans were washed		670 000		110 000

TABLE 10.—*Concluded*

No. of can	First washing—washing powder		Second washing—plain water	
	Bacteria removed from washed cans by one liter of rinse water	Germ content of wash water, per cc.	Bacteria removed from washed cans by one liter of rinse water	Germ content of wash water, per cc.
Before washing		20 500		5 500
31	58 000 000		6 400 000	
32	1 023 000 000		260 000 000	
33	777 000 000		97 000 000	
34	98 000 000		25 000 000	
35	28 000 000		2 400 000	
After 5 cans were washed		400 000		140 000
Before washing		19 000		18 200
36	40 000 000		17 600 000	
37	3 000 000		1 000 000	
38	5 700 000 000		2 830 000 000	
39	753 000 000		96 600 000	
40	194 000 000		11 000 000	
41	1 153 000 000		250 000 000	
42	4 400 000 000		1 066 600 000	
43	173 000 000		10 100 000	
After 8 cans were washed		14 000 000		450 000

As the process of washing proceeded, the number of bacteria in the wash water always increased. The thirty-two cans recorded in Table 8 were washed in water containing one percent of washing powder. Before any cans were washed, the water had 100,000 bacteria per cubic centimeter. After 12 cans were washed, the germ content of the water increased to 3,210,000 bacteria; after 22 cans were washed it increased to 3,420,000; and after 32 cans were washed it became 5,100,000. The water in which the cans in Table 9 were washed contained no washing powder. Its initial germ content was 155,000 bacteria per cubic centimeter, and after 15 cans were washed in it, its germ content increased to 457,000 bacteria. Similar results were obtained in Tables 10 and 11, where a new lot of wash water was prepared for every five to nine cans. In one case the initial germ content of the wash water was 28,000 bacteria per cubic centimeter, and after 5 cans were washed, its germ content increased to 20,000,000 bacteria.

The number of bacteria added to the cans by the wash water depends naturally on the germ content of the water and also on the amount of the water left in the cans. Several trials on this point demonstrated that from 10 to 25 cc. of water adhere to the inner surface of a can.

TABLE 11.—GERM CONTENT OF WASH WATER, AND OF CANS WASHED TWICE IN SUCCESSION; FIRST IN PLAIN WATER, THEN IN WASHING-POWDER SOLUTION

(New lot of 25 gallons of water used for every 5 to 9 cans)

No. of can	First washing—plain water		Second washing—washing powder	
	Bacteria removed from washed cans by one liter of rinse water	Germ content of wash water, per cc.	Bacteria removed from washed cans by one liter of rinse water	Germ content of wash water, per cc.
Dairy A				
Before washing		400		13 200
1	340 000 000		100 000	
2	1 000 000			
3	2 000 000		7 000 000	
4	277 000 000			
5	4 000 000		4 000 000	
After 5 cans were washed		11 800		47 600
Before washing		500		15 400
6	7 000 000		500 000	
7	24 000 000		400 000	
8	17 000 000		100 000	
9	1 000 000		100 000	
10	3 000 000			
After 5 cans were washed		14 200		44 400
Before washing		1 400		3 300
11	1 000 000		800 000	
12	7 000 000		7 000 000	
13	14 000 000		300 000	
14	3 000 000		800 000	
15	2 000 000		700 000	
16	1 000 000		1 000 000	
17	2 000 000		1 700 000	
18	5 000 000		1 300 000	
19	232 000 000		17 900 000	
After 9 cans were washed		200 000		94 000
Before washing		12 900		6 100
20	9 000 000		620 000	
21	1 000 000		580 000	
22	1 100 000		620 000	
23	1 200 000		770 000	
24	1 300 000		700 000	
25	400 000		790 000	
26	1 200 000		830 000	
After 7 cans were washed		69 000		.....

TABLE 11.—*Concluded*

No. of can	First washing—plain water		Second washing—washing powder	
	Bacteria removed from washed cans by one liter of rinse water	Germ content of wash water, per cc.	Bacteria removed from washed cans by one liter of rinse water	Germ content of wash water, per cc.
		Dairy B		
Before washing		......		200
27	3 350 000 000		115 200 000	
28	970 000 000		23 700 000	
29	3 630 000 000		143 300 000	
30	140 000 000		9 600 000	
31	450 000 000		500 000	
After 5 cans were washed		4 800 000		510 000
Before washing		1 400		28 000
32	1 084 000 000		783 000 000	
33	11 000 000		2 700 000	
34	3 416 000 000		355 000 000	
35	132 000 000		82 000 000	
36	26 000 000		9 800 000	
After 5 cans were washed		1 200 000		600 000
Before washing		......		107 000
37	37 000 000		82 700 000	
38	55 000 000		66 000 000	
39	184 000 000		64 700 000	
40	748 000 000		123 300 000	
41	33 000 000		10 300 000	
42	563 000 000		100 300 000	
43	25 000 000		22 000 000	
44	47 000 000		14 800 000	
After 8 cans were washed		14 400 000		450 000

Cans 31 and 32 in Table 8 were washed in the same water within one minute of each other. In Can 31 the bacteria numbered 40,330,000,000 and in Can 32, 270,000,000. The germ content of the wash water at this point was 5,100,000 bacteria per cubic centimeter. If the number of bacteria in these two cans was due to the wash water alone, it would have required 53 cc. of the water to have supplied the number in Can 32, while in Can 31 it would have required 7,907 cc. of the water. Similar calculations for each can in these tables show that in some cans the relatively small numbers of bacteria correspond somewhat closely to the number of bacteria in the amount of the water that may adhere to them. However, in many of the cans the number is too large to be accounted for by the wash-water contamination alone. In addition, there appears to be no gradual increase in the germ content of the consecutively washed cans. This leads to the conclusion, therefore, that the exceptionally large numbers of bacteria in the washed cans had some other source than the wash water.

In 1889 Conn stated that "bacteria gather upon the sides of the utensils and develop in the minute portions of milk, grease, and other matter from which it is difficult to free the vessels completely by washing." The data in this experiment support Conn's conclusion and further emphasize the striking capacity of the bacteria to multiply in the extremely minute portions of the milk, fat, and other matter, and to adhere to the walls of the cans. The large numbers of bacteria found in cans may be accounted for on the ground that the cans are difficult to clean thoroly, and that in the traces of this dirt numerous bacteria are imbedded and then are loosened by the washing process and subsequently removed by rinsing.

The purpose of this experiment was also to show the influence of the washing powder upon the germ content of the wash water and the washed cans. The cans listed in Table 8 were washed in water containing washing powder and those in Table 9 in plain water. Those shown in Tables 10 and 11 were washed twice in succession, half of them in washing-powder solution first and then in plain water, and half in plain water first and then in washing-powder solution. A perusal of these tables shows that the washing powder exerted no discernable influence upon the germ content of the wash water or of the washed cans. The germ content of the wash water increased during the washing process to about the same extent in the plain water and in the washing-powder solution, and many of the cans in both cases had extremely large numbers of bacteria.

It is customary in some dairies to wash a large number of utensils in the same lot of wash water, and then not to rinse them sufficiently with clean water or not to rinse them at all. Such practice results in seeding the wash water with large numbers of bacteria which were present in the dirt and in the milk that adhere to the walls of the utensils. When utensils are washed in such a manner, some may contain a larger number of bacteria after they are washed than they contained before they were washed.

Naturally the object of the washing process is to remove the dirt and the milk residues from the can, and the completeness with which it accomplishes this result is the true measure of its success. A reduction of the germ life in the can is ordinarily accomplished at the same time, but this reduction cannot be carried to satisfactory limits by the washing process without an undue expense for water, heat, and washing powder. The destruction of the germ life in the cans is ordinarily accomplished more economically and more completely by the direct application of steam.

BACTERIA FOUND IN BOTTLES FRESHLY WASHED AND IN BOTTLES STANDING TWENTY-FOUR HOURS

The washing of milk bottles is in a measure comparable to that of cans. Like cans, the bottles are washed in the same water in large numbers. They are returned to the dairy at times in dirty condition and frequently contain traces of milk with high germ content.

In the dairy in which this experiment was conducted, it was the custom to wash from 150 to 200 bottles in a vat containing about 60 gallons of warm water to which was added 5 pounds of sodium-carbonate washing powder. The bottles were scrubbed with a steam-driven brush, and then rinsed in another vat containing about 60 gallons of tap water; they were not steamed. For the purpose of this experiment two sets of the washed bottles, nine to fourteen in each set, were selected from each of fourteen different lots for study.

In order to obtain two comparable sets of bottles, selection was made in the following manner: The first two bottles washed were taken, then the eleventh and twelfth, then the twenty-first and twenty-second, and so on until all the bottles were washed. Those having odd numbers constituted the first set and those with even numbers the second set. The bottles in the first set were examined immediately after being washed and those in the second set after they had been kept inverted twenty-four hours on a wire rack. The examination consisted in rinsing each bottle with 100 cc. of sterile water and determining the number of bacteria in the water. The results of the examination of 308 bottles are given in Table 12.

The number of bacteria found in these bottles was variable and in some cases large. Among the bottles examined immediately after washing 25, or 16.2 percent, had more than one million bacteria, and 129, or 83.8 percent, had less than one million. The largest number of bacteria found in any one bottle was 40,660,000, and the smallest was 20,000.

The bottles that were held twenty-four hours after they were washed were found to be dry and free from bad odors. Eighty-four of these, or 54.5 percent, had more than one million bacteria, and 70, or 45.5 percent, had less than one million. The largest number of bacteria found was 231,700,000, and the smallest number was 3,000.

It will be observed that some of the bottles examined immediately after they were washed had a larger number of bacteria than some of the bottles held twenty-four hours. On the average, however, there was a decided increase in the number of bacteria in the bottles which were held twenty-four hours. This is brought out more clearly by calculating the average number of bacteria per bottle on each of the different days. These averages are given in Table 13.

The averages in Table 13 show that, in all cases, the set of bottles held twenty-four hours averaged more bacteria than the corresponding

TABLE 12.—NUMBER OF BACTERIA IN BOTTLES FRESHLY WASHED AND TWENTY-FOUR HOURS LATER: DAIRY A

(As determined by rinsing each bottle with 100 cc. of sterile water)

Total number of bacteria in bottles—				Total number of bacteria in bottles—			
No. of bottle	Freshly washed	No. of bottle	24 hours after washing	No. of bottle	Freshly washed	No. of bottle	24 hours after washing
	June 20		*June 20-21*		*June 21*		*June 21-22*
1	3 800 000	2	47 000 000	25	110 000	26	3 040 000
3	6 000 000	4	68 300 000	27	110 000	28	36 500 000
5	5 200 000	6	120 000 000	29	140 000	30	61 330 000
7	4 700 000	8	123 000 000	31	110 000	32	11 800 000
9	4 300 000	10	107 000 000	33	90 000	34	48 670 000
11	4 500 000	12	15 500 000	35	120 000	36	22 330 000
13	15 000 000	14	36 000 000	37	110 000	38	29 330 000
15	7 900 000	16	231 700 000	39	490 000	40	36 330 000
17	6 100 000	18	18 700 000	41	140 000	42	68 000 000
19	11 300 000	20	64 600 000	43	40 660 000	44	72 330 000
21	8 000 000	22	27 700 000				
23	6 600 000	24	163 000 000				
	June 22		*June 22-23*		*June 23*		*June 23-24*
45	2 950 000	46	4 700 000	63	30 000	64	2 290 000
47	100 000	48	100 000	65	2 730 000	66	1 280 000
49	340 000	50	5 130 000	67	40 000	68	6 030 000
51	520 000	52	15 430 000	69	200 000	70	15 000 000
53	110 000	54	6 570 000	71	70 000	72	8 570 000
55	270 000	56	20 670 000	73	120 000	74	9 870 000
57	850 000	58	5 400 000	75	190 000	76	34 000 000
59	210 000	60	910 000	77	80 000	78	1 830 000
61	780 000	62	180 000	79	100 000	80	3 190 000
	June 26		*June 26-27*		*June 27*		*June 27-28*
81	630 000	82	360 000	101	43 000	102	30 000
83	410 000	84	30 500 000	103	315 000	104	2 700 000
85	320 000	86	430 000	105	83 000	106	480 000
87	340 000	88	300 000	107	68 000	108	210 000
89	760 000	90	30 000	109	40 000	110	10 000
91	400 000	92	120 000	111	335 000	112	470 000
93	230 000	94	170 000	113	54 000	114	160 000
95	590 000	96	140 000	115	48 000	116	10 000
97	250 000	98	350 000	117	303 000	118	1 490 000
99	220 000	100	120 000	119	71 000	120	2 020 000
	June 28		*June 28-29*		*June 30*		*June 30— July 1*
121	62 000	122	370 000	139	305 000	140	830 000
123	295 000	124	80 000	141	243 000	142	1 920 000
125	175 000	126	140 000	143	279 000	144	10 000
127	901 000	128	230 000	145	30 000	146	750 000
129	170 000	130	100 000	147	600 000	148	2 070 000
131	220 000	132	15 160 000	149	61 000	150	630 000
133	333 000	134	80 000	151	2 430 000	152	470 000
135	5 733 000	136	1 500 000	153	93 000	154	250 000
137	1 130 000	138	90 000	155	41 000	156	320 000
				157	61 000	158	260 000

TABLE 12.—*Concluded*

Total number of bacteria in bottles—				Total number of bacteria in bottles—			
No. of bottle	Freshly washed	No. of bottle	24 hours after washing	No. of bottle	Freshly washed	No. of bottle	24 hours after washing
	Sept. 25, a. m.		*Sept. 25-26, a. m.*		*Sept. 25, p. m.*		*Sept. 25-26, p. m.*
159	450 000	160	90 000	183	43 000	184	13 330 000
161	36 000	162	3 000	185	46 000	186	1 926 000
163	40 000	164	3 090 000	187	66 000	188	2 826 000
165	26 000	166	853 000	189	36 000	190	3 026 000
167	50 000	168	3 000	191	66 000	192	310 000
169	50 000	170	250 000	193	43 000	194	310 000
171	63 000	172	43 000	195	33 000	196	930 000
173	36 000	174	660 000	197	50 000	198	350 000
175	40 000	176	76 000	199	30 000	200	630 000
177	53 000	178	396 000	201	740 000	202	316 000
179	66 000	180	1 300 000	203	66 000	204	2 773 000
181	20 000	182	206 000	205	80 000	206	150 000
	Sept. 27, a. m.		*Sept. 27-28, a. m.*		*Sept. 27, p. m.*		*Sept. 27-28, p. m.*
207	83 000	208	4 880 000	231	340 000	232	4 560 000
209	593 000	210	4 800 000	233	350 000	234	3 746 000
211	90 000	212	110 000	235	540 000	236	5 300 000
213	276 000	214	4 226 000	237	396 000	238	11 400 000
215	276 000	216	4 073 000	239	1 553 000	240	6 933 000
217	283 000	218	8 600 000	241	300 000	242	1 753 000
219	110 000	220	313 000	243	740 000	244	3 700 000
221	100 000	222	320 000	245	540 000	246	2 950 000
223	163 000	224	13 000	247	370 000	248	13 660 000
225	2 493 000	226	3 396 000	249	660 000	250	10 300 000
227	363 000	228	6 000	251	1 043 000	252	1 336 000
229	570 000	230	660 000	253	1 090 000	254	12 330 000
	Sept. 29, a. m.		*Sept. 29-30, a. m.*		*Oct. 2, p. m.*		*Oct. 2-3, p.m.*
255	6 986 000	256	6 400 000	285	73 000	286	50 000
257	280 000	258	9 530 000	287	57 000	288	10 000
259	3 160 000	260	2 670 000	289	99 000	290	60 000
261	450 000	262	2 100 000	291	77 000	292	10 720 000
263	340 000	264	6 020 000	293	165 000	294	80 000
265	436 000	266	3 995 000	295	237 000	296	30 000
267	230 000	268	2 600 000	297	63 000	298	110 000
269	513 000	270	4 606 000	299	46 000	300	10 000
271	253 000	272	3 853 000	301	44 000	302	2 020 000
273	8 700 000	274	4 253 000	303	56 000	304	270 000
275	350 000	276	3 366 000	305	74 000	306	260 000
277	286 000	278	1 963 000	307	64 000	308	110 000
279	400 000	280	60 000				
281	386 000	282	3 000				
283	296 000	284	26 000				

set of the same day examined immediately after the washing. The average number of bacteria in all the 154 bottles examined immediately after the washing was 1,271,950 per bottle, and in those held twenty-four hours it was 12,283,490 per bottle.

One quart is approximately 950 cubic centimeters; so that if these bottles had been filled with milk, the germ content of the milk would have been increased, on the average, by 1,339 bacteria per cubic centimeter by the freshly washed bottles and 12,930 bacteria per cubic centimeter by the bottles held twenty-four hours after the washing. From these results it is evident that bottles washed but not steamed may have an appreciable effect upon the germ content of milk, especially when they are held for some hours before being filled.

TABLE 13.—AVERAGE NUMBER OF BACTERIA IN WASHED BOTTLES

Date, 1916	Number of bottles	Bottles freshly washed	Bottles held 24 hours after washing
June			
20	12	6 950 000	85 200 000
21	10	4 208 000	38 966 000
22	9	681 000	6 565 000
23	9	395 000	9 115 000
26	10	415 000	3 252 000
27	10	136 000	758 000
28	9	1 002 000	1 970 000
30	10	414 000	751 000
Sept.			
25 a.m.	12	78 000	581 000
25 p.m.	12	108 000	2 240 000
27 a.m.	12	450 000	2 616 000
27 p.m.	12	660 000	6 497 000
29 a.m.	15	1 538 000	3 429 000
Oct.			
2. p.m.	12	879 000	1 144 000
Average number of bacteria in 154 bottles......		1 271 950	12 283 490

PART II.—INFLUENCE SHOWN BY EXAMINATION OF THE MILK

The four experiments reported in this part were designed to ascertain the influence of the various unsteamed utensils upon the germ content of milk, in actual dairy operations. This influence was measured by the difference in the germ content of milk handled in steamed and in unsteamed utensils.

The utensils were washed as described on page 219. The steaming consisted in holding the utensils in a chamber filled with flowing steam, for about an hour, with the exception that some of the pails and cans were held over a jet of steam for two to three minutes. The thoroness of the steaming of the utensils was always tested bacteriologically and found to be satisfactory.

COLLECTIVE INFLUENCE OF UTENSILS AT THE BARN

This experiment was designed to measure the collective influence on the germ content of milk of unsteamed pails, strainers, and cans used at three dairy barns. In each barn the milk was drawn into small-topped pails and strained thru a combination cloth and wire strainer into eight-gallon cans. After each milking, the utensils were washed in water containing washing powder, rinsed in a vat of tap water, and placed on a rack. At each milking a new strainer cloth was used. The utensils were used, as a rule, in from six to twelve hours after being washed, altho in a few cases cans were held twenty-four to thirty-six hours.

Normally, the utensils were steamed after being washed at these dairy farms; but in order to bring out the influence of unsteamed utensils, the steaming was omitted on some days. The samples of milk were removed from the cans for bacteriological examination within one hour after milking, both when the utensils had been steamed and when they had been left unsteamed. The results of bacteriological examination are given in Tables 14 to 19.

These tables present a striking contrast between the germ content of milk handled in steamed utensils and that handled in unsteamed utensils. When the pails, the strainers, and the cans were steamed, only 4 cans of milk out of 34 in Barn I, and 3 out of 35 in Barn II had a germ content above 10,000 bacteria per cubic centimeter. The average germ content for all the milk handled in steamed utensils was 4,865 bacteria per cubic centimeter in Barn I and 3,157 in Barn II. The results from Barn III were somewhat higher, the average germ content being 12,400 per cubic centimeter for steamed utensils.

On the other hand, when the utensils were not steamed, the germ content of the milk became higher and more variable. Of the 117 cans of milk from the three barns, 7 had more than one million bacteria per cubic centimeter, 81 had above 100,000, and only 2 had less than 10,000. The highest germ content in a single can was 2,623,100 and the lowest was 7,100. The average germ content for all the milk handled in unsteamed utensils was 311,000 for Barn I, 326,880 for Barn II, and 218,930 for Barn III.

The bacteria that were found in the milk in these cans were contributed by all the sources of contamination to which the milk was exposed on its way from the udder to the cans. The difference between the germ content of the milk handled in the steamed utensils and that

TABLE 14.—GERM CONTENT OF MILK HANDLED IN STEAMED PAILS, STRAINERS, AND CANS: BARN I

No. of can	Oct. 3, 1914, a.m.	Oct. 4, a.m.	May 12, 1915, a.m.	May 13, a.m.	May 21, a.m.	May 22, a.m.	May 25, a.m.
	Number of bacteria per cc. of milk in cans						
1	1 904	1 690	6 805	3 617	15 522	12 075	826
2	2 486	1 267	5 727	3 482	6 200	1 170	2 600
3	3 280	....	5 542	3 032	4 950	5 285	3 592
4	2 502	....	7 290	1 660	8 885	3 952	10 510
5	....	....	10 720	3 500	....	4 997	2 712
6	....	....	.....	....	....	4 652	5 837
7	....	....	.....	....	....	2 555	4 600

TABLE 15.—GERM CONTENT OF MILK HANDLED IN UNSTEAMED PAILS, STRAINERS, AND CANS: BARN I

No. of can	May 3, 1915, p.m.	May 4, a.m.	May 5, p.m.	May 6, a.m.	May 6, p.m.	May 7, a.m.
	Number of bacteria per cc. of milk in cans					
1	78 700	38 400	624 500	887 500	108 000	120 000
2	.....	45 600	......	763 100	779 000	39 100
3	.....	130 500	......	57 100	......	23 200
4	.....	7 100	......	18 200	......	30 200
5	.....	28 800	......	2 623 100	......	31 200
6	.....	.....	......	9 200	......	90 400

TABLE 16.—GERM CONTENT OF MILK HANDLED IN STEAMED PAILS, STRAINERS, AND CANS: BARN II

No. of can	Oct. 3, 1914, a.m.	May 12, 1915, a.m.	May 12, p.m.	May 13, a.m.	June 1, p.m.	June 3, p.m.
	Number of bacteria per cc. of milk in cans					
1	785	5 960	850	1 605	6 507	1 237
2	610	1 500	1 985	1 820	1 297	942
3	837	2 187	1 616	2 077	11 837	785
4	235	19 400	1 722	1 040	4 515	1 205
5	770	886	1 977	6 015	4 692	1 777
6	...	....	4 027	2 816	....	10 667
7	...	....	2 456	....	....	.....
8	...	....	1 837	....	....	.....

of the milk handled in the unsteamed utensils gives approximately the number of bacteria contributed by the unsteamed pails, strainers, and cans. From the foregoing figures this difference is seen to be 306,135 bacteria per cubic centimeter for the milk handled in Barn I; 323,723 bacteria per cubic centimeter for the milk handled in Barn II; and 206,530 bacteria per cubic centimeter for the milk handled in Barn III. In other words, the unsteamed pails, strainers, and cans added to the milk 64 times as many bacteria as all the other sources of contamination at Barn I, 103 times as many in Barn II, and 18 times as many in Barn III.

TABLE 17.—GERM CONTENT OF MILK HANDLED IN UNSTEAMED PAILS, STRAINERS, AND CANS: BARN II

No. of can	April 27, 1915 a.m.	April 28, p.m.	April 29, p.m.	May 3, a.m.	May 3, p.m.	May 4, a.m.
	Number of bacteria per cc. of milk in cans					
1	212 000	89 200	18 400	828 000	118 700	426 200
2	310 000	363 500	52 800	852 000	77 100	575 000
3	97 300	275 800	21 500	410 500	83 900	254 700
4	123 500	111 200	32 800	1 124 000	195 800	237 000
5	120 000	123 600	35 100	369 000	61 500	554 000
6	124 700	422 500	62 300	703 000	111 100	445 000
7	133 700	485 000	73 500	......	143 200	......
	May 4, p.m.	May 5, a.m.	May 5, p.m.	May 6, a.m.	May 6, p.m.	May 7, a.m.
1	75 000	538 000	208 500	1 135 000	127 400	690 000
2	65 300	172 200	127 600	1 347 200	159 500	393 700
3	114 100	762 500	399 700	544 600	298 400	127 700
4	158 300	630 500	170 200	356 500	221 100	127 900
5	62 500	139 000	223 700	1 053 700	107 500	1 520 000
6	348 000	......	434 500	392 500	286 400	374 000
7	271 500	......	195 700	......	279 000	......

TABLE 18.—GERM CONTENT OF MILK HANDLED IN STEAMED PAILS, STRAINERS, AND CANS: BARN III

No. of can	May 11, 1915 p.m.	May 12, a.m.	May 12, p.m.	May 13, a.m.	June 1, p.m.	June 3, p.m.
	Number of bacteria per cc. of milk in cans					
1	8 295	41 150	9 652	17 405	5 442	6 027
2	7 980	10 737	3 782	4 833	13 112	20 490

TABLE 19.—GERM CONTENT OF MILK HANDLED IN UNSTEAMED PAILS, STRAINERS, AND CANS: BARN III

No. of can	May 3, 1915 a.m.	May 3, p.m.	May 4, a.m.	May 4, p.m.	May 5, a.m.	May 5, p.m.	May 6, a.m.	May 6, p.m.	May 7, a.m.
	Number of bacteria per cc. of milk in cans								
1	130 000	40 000	39 800	51 700	154 700	109 000	335 500	183 400	210 500
2	25 400	37 200	75 400	121 700	214 200	1 538 500	495 500	94 100	84 100

Influence of Unsteamed Bottle Filler upon Germ Content of Milk

The bottle filler used for this experiment was the "double-end, four-quart and five-pint filler" shown in Fig. 1. It consisted of a tank and nine valves, each valve having a stem, a sleeve, an air tube, a wire coil spring, and a rubber washer.

In washing the bottle filler the valves were taken apart and placed inside the filler tank. The tank and all the parts were then scrubbed with a brush and washing powder and rinsed with a hose. After the bottler was cleaned in this manner, it remained standing in the milk room about twenty hours before it was used again. When it was to be steamed, it was covered with a galvanized iron lid, the valve openings were stopped with corks, and the steam was allowed to flow into it for thirty minutes. The steaming was done about one hour before bottling, and its thoroness was always tested by a bacteriological examination. The milk bottles were steamed in all cases.

From 300 to 400 quarts of milk were pasteurized and bottled each day. The milk was pasteurized in a vat; then cooled in the same vat by passing brine thru a coil revolving in the milk; and then it was bottled immediately. Samples of the milk were taken from the pasteurizing vat just before bottling, and then during the process, from the first bottle filled, thru one of the four valves and then from every ninth bottle filled thru the same valve. Since there were four valves in the bottle filler, every ninth bottle filled thru one valve was actually every thirty-sixth bottle filled.

Table 20 gives the germ content of the milk when the bottle filler was steamed, and Table 21 when it was washed but not steamed. The bottles in both cases were steamed before being used.

TABLE 20.—GERM CONTENT OF PASTEURIZED AND BOTTLED MILK WHEN BOTTLE FILLER AND BOTTLES WERE STEAMED: DAIRY A

Samples of milk from:	Jan. 4, 1916	Jan. 5	Jan. 6	Jan. 7	Jan. 8	Average
	Number of bacteria per cc. of milk					
Pasteurizer	1 832	265	1 497	100	922	923
1st bottle..........	1 887	420	1 270	65	1 432	1 015
36th "	2 782	260	1 310	40	1 225	1 123
72d "	2 165	305	1 637	80	916	1 021
108th "	2 257	255	1 287	50	1 090	969
144th "	2 250	320	2 027	60	832	1 098
180th "	2 167	230	1 182	395	1 180	1 031

Table 20 shows that when the bottle filler was steamed shortly before use, the germ content of the bottled milk was approximately the same as that in the pasteurizing vat. If any increase took place, it was not measurable. When, however, the bottle filler, which had

TABLE 21.—GERM CONTENT OF PASTEURIZED AND BOTTLED MILK WHEN BOTTLE FILLER WAS NOT STEAMED: DAIRY A

Samples of milk from:	Dec. 17, 1915	Dec. 18	Dec. 19	Dec. 21	Dec. 22	Dec. 23	Dec. 24	Dec. 25	Dec. 29	Dec. 30	Average
	Number of bacteria per cc. of milk										
Pasteurizer	190	60	35	60	45	203	105	35	30	80	84
1st bottle.......	165 000	209 600	80 900	58 900	189 750	69 100	46 750	46 530	101 800	720	96 900
36th ”	31 550	13 580	25 450	4 240	44 500	5 730	11 850	8 880	13 770	480	16 000
72d ”	25 000	8 870	13 710	4 000	20 250	13 600	6 080	10 930	12 200	530	11 500
108th ”	18 700	5 730	16 040	2 800	38 100	6 090	4 210	5 610	10 240	190	10 800
144th ”	14 100	6 060	7 240	2 070	27 700	2 900	3 890	5 230	7 350	270	7 680
180th ”	8 650	3 620	6 100	1 420	26 200	3 240	3 620	4 920	4 150	220	6 200
216th ”	6 340	2 740	3 820	1 150	16 400	1 220	2 060	2 740	3 840	120	4 040
252d ”	3 700	1 800	2 510	810	13 130	2 010	1 730	1 350	3 520	140	3 070
298th ”	4 240	1 870	2 650	340	15 600	2 170	1 210	3 290	3 960	100	3 540
334th ”	2 290	1 130	2 130	360	6 210	3 990	800	2 360	2 430	...	2 410
370th ”	....	....	1 440	360	6 720	....	1 250	....	1 670	...	2 288

stood for twenty hours after washing, was not steamed, a conspicuous increase in the germ content of the bottled milk took place. Table 21 for instance, shows that on December 18 the germ content of the milk in the pasteurizing vat was but 60 bacteria per cubic centimeter while in the first bottle filled it was increased to 209,600 bacteria.

The averages shown in the last column in Table 21 present a striking illustration of the effect of the unsteamed bottle filler on the germ content of the milk passed thru it. The average germ content of the milk before bottling was 84 bacteria per cubic centimeter; of the first bottle filled it was 96,900; and of the last bottle, 2,288. There was evidently a gradual washing out of the bacteria of the bottle filler by the milk passed thru it, the greatest proportion being removed by the first milk. However, the effect of the unsteamed bottler was evident even in the last bottle filled.

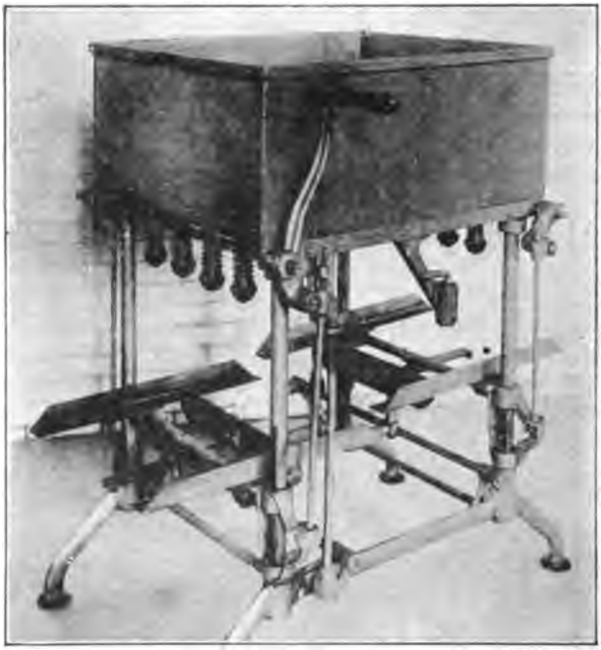

FIG. 1.—BOTTLE FILLER USED IN THE EXPERIMENT

COLLECTIVE INFLUENCE OF UTENSILS AT THE BARN AND AT THE DAIRY

In the barn and in Dairy A, in which this study was conducted, about 100 to 200 quarts of milk came into contact with the utensils during the process of milking. The utensils used comprized five pails, two strainers, two weighing pails, one sanitary tube fifteen feet long,

TABLE 22.—GERM CONTENT OF BOTTLED MILK WHEN ALL UTENSILS WERE STEAMED: DAIRY A

Samples of milk from:	Sept. 18, 1914	Sept. 29	Oct. 1	Oct. 21	Oct. 26	Oct. 27	Oct. 28	Oct. 29	Oct. 31	Nov. 2
	Number of bacteria per cc. of milk									
1st bottle............	6 052	5 977	3 825	15 596	4 827	3 850	2 825	2 882	4 492	4 972
16th ”	6 262	6 850	3 820	7 502	2 890	3 957	3 787	3 297	4 455	4 937
36th ”	5 922	2 770	2 407	5 140	2 307	3 265	3 287	3 430	4 262	4 302
64th ”	**4 542**	**2 600**	**3 406**	....	....	....	....	....	....	....

TABLE 23.—GERM CONTENT OF BOTTLED MILK WHEN UTENSILS WERE NOT STEAMED: DAIRY A

Samples of milk from:	Sept. 29, 1914	Oct. 2	June 25, 1915	June 25	June 26	June 27	June 29	June 29	June 30	June 30	July 1	July 1
	Number of bacteria per cc. of milk											
1st bottle...	**155 000**	**190 000**	**81 000**	**330 750**	**734 000**	**75 750**	**347 000**	**948 000**	**492 500**	**342 500**	**265 000**	**667 500**
16th ” ...	**60 500**	**210 000**	**64 500**	**410 500**	**1 085 000**	**760 000**	**319 500**	**684 750**	**175 500**	**99 687**	**208 250**	**161 250**
36th ” ...	**73 600**	**252 000**	**51 000**	**289 750**	**348 000**	**75 500**	**129 250**	......	**162 500**	**108 250**	**187 000**	**162 500**
64th ” ...	**84 875**	......	**127 500**	......	**408 000**	**68 000**	**56 000**	......	**123 500**	**100 875**	**339 000**	**128 750**
96th ” ...	.....	......	.....	......	**137 000**	.....	**59 400**	......	**190 000**	......	......	......
124th ” ...	.....	......	.....	......	**131 250**	.....	**76 600**	......	......	......	......	......
144th ” ...	.....	......	.....	......	**123 500**	.....	.....	......	......	......	......	......

one clarifier, one tubular cooler, five cans, one stirring dipper, and one bottle filler.

The utensils were steamed on certain days, while on other days they were only washed, rinsed, and placed on a rack until needed. The bottles were steamed in all cases.

The milk was bottled within two hours after milking, and the samples were taken from the consecutively filled bottles at definite intervals. The germ content of the milk samples from steamed utensils is shown in Table 22, and from unsteamed utensils in Table 23.

The influence of the unsteamed utensils is measured by the difference in the germ content of the milk handled in steamed and in unsteamed utensils. The germ content of the milk when steamed utensils were used represents approximately the extent of contamination from sources other than from the utensils. It is seen from Table 22 that in most cases the bottled milk handled in steamed utensils had less than 5,000 bacteria per cubic centimeter, and in only one case was the germ content over 10,000. On the other hand, when unsteamed utensils were used, as shown in Table 23, the germ content of the bottled milk became variable and high. The lowest count was 51,000 bacteria per cubic centimeter and the highest 1,085,000 bacteria.

These results show that unsteamed utensils were the most important source of bacterial contamination at this dairy. They also show that when the utensils were thoroly steamed, milk of certified quality was produced without any difficulty.

INFLUENCE OF INDIVIDUAL UTENSILS AT THE BARN AND AT THE DAIRY

This experiment on the influence of the individual utensils was carried on at the same barn and dairy as the preceding experiment. All the utensils were washed and rinsed about eight hours previous to use, and only the bottles were steamed. The effect of the utensils that hold milk, such as cans and pails, was measured from samples of milk taken directly from them. The effect of such utensils as strainers and clarifiers, thru which milk passes, was measured from samples taken from the milk after it had run into steamed cans.

At each milking two lots of milk, of about six gallons each, were passed one after the other thru each of the utensils up to the bottle filler, and samples of milk were removed after the milk came into contact with each utensil. Both lots of milk were then mixed in the bottle filler and bottled. The results of the bacteriological examination of these samples are presented in Table 24.

In the preceding experiments it was shown that when the utensils were steamed, the bottled milk at this dairy rarely exceeded 5,000 bacteria per cubic centimeter (see Table 22). It may be assumed, therefore, with reasonable certainty that the milk, when this experiment was performed, did not receive more than 5,000 bacteria per cubic

TABLE 24.—INCREASE IN GERM CONTENT OF MILK DUE TO THE VARIOUS UNSTEAMED UTENSILS: DAIRY A
(Number of bacteria per cc. of milk)

Germ content of milk due to barn factors plus:	Oct. 5, 1915, p.m.	Oct. 6, p.m.	Oct. 7, a.m.	Oct. 7, p.m.	Oct. 8, a.m.	Oct. 8, p.m.	Oct. 9, a.m.	Oct. 9, p.m.	Oct. 10, p.m.
					First Lot of 25 Liters of Milk				
Three pails............	5 150	34 350	91 000	74 750	183 500	76 750	63 500	87 250	107 000
Strainer	12 225	27 850	112 500	70 000	188 000	60 000	62 750	122 500	132 750
Clarifier tank..........	15 250	39 225	105 750	77 250	172 250	58 000	72 250	136 250	189 250
Clarifier	30 000	101 700	152 250	280 750	246 500	90 500	346 250	568 000	1 622 500
Cooler	25 000	100 560	140 000	301 500	302 250	83 000	348 250	456 000	1 840 000
					Second Lot of 25 Liters of Milk				
Three pails............	10 575	18 860	41 500	42 250	54 500	25 250	37 500	67 750	52 000
Strainer	14 650	29 900	38 750	44 750	56 500	24 750	37 750	80 750	88 750
Clarifier tank..........	13 700	30 125	51 250	48 000	63 250	39 000	45 750	89 500	103 750
Clarifier	15 600	46 875	37 250	82 500	75 500	42 500	73 250	180 750	361 500
Cooler	18 425	53 925	51 500	92 750	89 500	43 750	94 750	225 250	543 750
					The Two Lots of Milk Mixed in Bottle Filler				
Bottle-filler tank	54 250	167 500	196 250	272 250	281 000	107 250	344 000	446 750	1 385 000
1st bottle...............	189 000	1 479 000	987 500	634 000	500 000	600 000	550 000	785 000	1 415 000
9th ”	.....	......	......	......	......	......	550 000	785 000	1 280 000
17th ”	66 950	196 750	229 500	277 750	330 250	157 500	342 000	......	1 072 000
25th ”	.....	......	......	......	......	......	......	587 500	......
33d ”	51 875	192 000	200 500	308 000	308 250	207 500	482 250	......	......
41st ”	.....	......	......	......	......	......	......	482 000	......

centimeter from the sources of contamination other than the utensils. The number of bacteria each utensil added to the milk and the cumulative effect of a number of utensils upon the germ content of the milk is very evident in Table 24. It is further emphasized in Table 25, where are shown the average numbers of bacteria that were added to the milk by each utensil and the average number per cubic centimeter of the milk.

TABLE 25.—AVERAGE NUMBER OF BACTERIA ADDED TO FIFTY LITERS OF MILK BY THE VARIOUS UNSTEAMED UTENSILS IN WHICH IT WAS HANDLED: DAIRY A

Source of bacteria	Number of bacteria per cc. of milk	Total number of bacteria
Sources other than utensils	5 000	250 000 000
3 pails	54 635	2 731 750 000
1 strainer	7 315	365 750 000
1 clarifier tank	8 038	401 900 000
1 clarifier	141 340	7 067 000 000
1 cooler	50 900	2 545 000 000
1 bottle-filler tank	83 246	4 162 300 000
Total	350 000	17 523 700 000
Total for utensils	345 000	17 273 700 000

Each utensil is seen to have contributed a different number of bacteria to the milk. The clarifier and the bottle filler were the most prolific sources. The clarifier added, on the average, 141,340 bacteria per cubic centimeter of the 50 liters of milk. The total number added by the bottle filler is difficult to estimate, since the valves of the filler added different numbers of bacteria to the consecutively filled bottles. A rough estimate shows that the tank and the four valves of the filler added approximately 436,000 bacteria per cubic centimeter of the milk.

It will be noticed from Table 24 that the first lot of 25 liters of milk passing thru the utensils became more heavily seeded with bacteria than the second lot of 25 liters. As the milk passed thru the valves of the filler into the bottles, the first bottles likewise became more heavily contaminated than those subsequently filled. There is a washing out of the bacteria from the utensil by the milk, so that the influence of a utensil depends on the amount of milk passed thru it as well as on the total number of bacteria in the utensil. It must therefore be borne in mind that in this experiment only 50 liters of milk came into contact with the utensils.

Considered as a whole, the accumulation of germ life in milk by contact with different utensils that are not steamed, frequently reaches a point where the keeping quality of the milk is seriously affected. The milk examined in this last experiment was less than two hours old. What would have been the germ content of this milk had its delivery to the consumer been delayed some twenty to forty hours, as happens in the milk business in large cities, is readily imagined.

SUMMARY

1. BACTERIA FOUND IN FRESHLY WASHED CANS.—An examination of 170 freshly washed but unsteamed milk cans showed the presence of large numbers of bacteria. Had these freshly washed cans been filled with sterile milk, the germ content of the milk would have varied from 197 to 2,557,000 bacteria per cubic centimeter and would have averaged 128,592 bacteria per cubic centimeter.

2. BACTERIA FOUND IN CANS THIRTY HOURS AFTER BEING WASHED.—Fifty cans washed, steamed, and left thirty hours uncovered and inverted on a rack, if filled with milk would have added to the milk an average of 8 bacteria per cubic centimeter. Fifty cans similarly cleansed but left thirty hours with the lids on, if filled with milk would have added to the milk an average of 1,816 bacteria per cubic centimeter.

Fifty cans washed but not steamed, and held thirty hours uncovered and inverted on a rack, if filled with milk would have added to the milk an average of 27,164 bacteria per cubic centimeter. Ten cans similarly cleansed but held thirty hours with the lids on, if filled with milk would have added to the milk an average of 128,730 bacteria per cubic centimeter.

3. BACTERIA FOUND IN CANS WASHED AND RETURNED TO THE FARM.—Ninety-one milk cans that had been washed, rinsed, and steamed at the dairy and covered with their lids, examined as they were about to be used on several dairy farms showed that had they been filled with milk they would have added to the milk an average of 23,523 bacteria per cubic centimeter. The treatment of these cans at the farms was not uniform, either as to their being kept covered or as to the length of time elapsing before their use.

4. SOURCES OF BACTERIA IN WASHED CANS.—A comparison of the germ content of each of 153 milk cans after the cans had been emptied and washed, but not rinsed or steamed, and the germ content of the milk previously held by the cans, in most cases revealed no direct relationship. However, taken in the whole, the dairy which received the milk with the higher germ content also had the cans with the higher germ content.

An examination of 134 freshly washed cans and of the water in which they were washed showed that the wash water became heavily seeded with bacteria during the washing process. However, the extremely large numbers of bacteria found in some of the washed cans could not be accounted for by contamination from the wash water. The most probable explanation of these extremely large numbers is that the bacteria are imbedded in small traces of grease and other matter on the inner walls of the can, and become loosened in the washing process.

5. BACTERIA FOUND IN BOTTLES FRESHLY WASHED AND IN BOTTLES STANDING TWENTY-FOUR HOURS.—An examination of 154 freshly washed but unsteamed milk bottles showed that had they been filled with sterile milk, the germ content of the milk would have averaged 1,339 bacteria per cubic centimeter, while an equal number of similar bottles, examined after an interval of twenty-four hours during which they had been left inverted on a rack, would have given a germ content to the milk of 12,930 bacteria per cubic centimeter.

6. COLLECTIVE INFLUENCE OF UTENSILS AT THE BARN.—An examination of 81 cans of milk at the farm ready for transportation to the dairy, when all utensils had been carefully steamed showed an average germ content of 6,807 bacteria per cubic centimeter. A similar examination of the milk in 117 cans from the same farms, when all utensils were similarly treated except that the steaming was omitted, showed an average germ content of 285,600 bacteria per cubic centimeter.

7. INFLUENCE OF UNSTEAMED BOTTLE FILLER UPON GERM CONTENT OF MILK.—When the bottle filler was carefully washed and steamed, it exerted no appreciable effect upon the germ content of the milk passing thru it. When it was similarly washed but not steamed, the germ content of the milk of the first bottle was increased on the average by 96,900 bacteria per cubic centimeter. The continued use of the bottle filler gradually washed the larger part of the germ life from the machine.

8. COLLECTIVE INFLUENCE OF UTENSILS AT THE BARN AND AT THE DAIRY.—A study of the collective influence of all the utensils that normally come into contact with the milk both at the barn and at the dairy showed that when all the utensils were carefully steamed the germ content of the milk in the bottles was about 4,566 bacteria per cubic centimeter. When similar conditions obtained except that the steaming of the utensils was omitted, the germ content of the milk approximated 257,240 bacteria per cubic centimeter.

9. INFLUENCE OF INDIVIDUAL UTENSILS AT THE BARN AND AT THE DAIRY.—Of all the various utensils coming into contact with the milk at the barn and at the dairy, the clarifier and the bottle filler when unsteamed proved to be the most prolific sources of contamination. The clarifier added an average of 141,340 bacteria per cubic centimeter to the fifty liters of milk passed thru it, while the bottle-filler tank and the four valves of the filler added approximately 436,000 bacteria per cubic centimeter to the same milk.

CONCLUSIONS

The fact that the dirt which falls into milk at the barn is readily visible in the milk has led to the conclusion that the barn is the principal source of the bacteria in milk. The results of this study, however, show that it is the utensils, rather than the barn, that are largely responsible for the excessive bacterial contamination of milk. The extent of the contamination of milk by the utensils is strikingly illustrated in one of the experiments in this study: when all the utensils commonly used for handling the milk at the barn and in the dairy were thoroly steamed, the bottled milk had uniformly only about 5,000 bacteria per cubic centimeter, but as soon as the steaming was omitted the bottled milk frequently contained several hundred thousand bacteria per cubic centimeter.

The cans used for shipping milk are a particularly prolific source of bacteria when they are washed at the dairy and returned to the farm without being thoroly steamed and dried. The number of bacteria usually added to the milk by such cans is many times larger than the number that would ordinarily get into the milk at the barn; the addition of a million bacteria per cubic centimeter of milk by such cans is not uncommon.

A detailed comparative study of the effect of the various other utensils at the barn and at the dairy suggests that the greatest contamination comes from the more complex apparatus, such as the clarifier and the bottle filler. In one of the experiments in this study, it was found that the pails added approximately eleven times as many bacteria to the milk as the barn influences, the strainer one and one-half times as many, the clarifier thirty times as many, the cooler ten times as many, and the bottle filler sixty times as many—a total of 112 times as many added by the utensils as by the barn factors.

It seems to the authors that in an attempt to produce milk with low germ content too much stress has been laid on practices of minor importance and the influence of utensils poorly steamed and not dried has been commonly neglected.

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BULLETIN NO. 205

THE GRASSES OF ILLINOIS

By EDNA MOSHER

URBANA, ILLINOIS, MARCH, 1918

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THE GRASSES OF ILLINOIS

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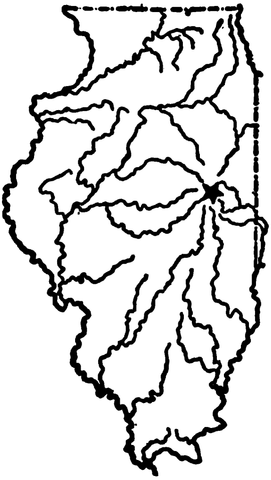

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FOREWORD

Dr. Mosher's monograph of the grasses of Illinois represents a type of work that is needed for every natural or economic group of Illinois plants. It is not a compilation or a perfunctory systematic account of plants known or thought to occur in Illinois; but it is based on personal examination of scattered earlier records and a critical verification of the meaning of the entries in them where specimens exist for such verification. The thoroness with which all available materials have been scanned is evident from the fact that of the two hundred and four species admitted by Dr. Mosher over one-fifth are now recorded for the first time as occurring in Illinois. That the nomenclature of the paper does not entirely conform to that of the latest general floras marks an added point of excellence, for it rests on the later and maturer judgment of Mrs. Agnes Chase (whose large personal herbarium was presented to the University several years ago) and Professor A. S. Hitchcock, who are admittedly the American authorities on grasses today, and whose aid has been given freely as the study progressed.

William Trelease

Urbana, March 20, 1918

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THE GRASSES OF ILLINOIS

BY EDNA MOSHER[1]

INTRODUCTION

According to the earlier botanists who studied the flora of Illinois, about two hundred species of plants were found on the original prairie and more than half of these were grasses. The grasses were probably the most characteristic plants of the prairie, the shorter and less conspicuous species forming a dense sod; the taller species usually forming large clumps from three to six feet tall, which were visible for a considerable distance. The original prairie is fast disappearing from the state of Illinois, and with it many of the species of grasses once included in its flora. The majority of the species which were abundant there are still found within the state, altho some of them are extremely rare. A number of the species have not been collected in Illinois in recent years and may not occur in the state at the present time. The grasses, however, still remain a prominent feature of the landscape, as anyone who has seen our great cornfields will testify. From an economic standpoint they are the most important plants of Illinois today, as the cultivated grasses called grains form a large percentage of the crops of the state. In addition there are the cultivated grasses of our pastures and meadows, many of which are introduced species, and all of which add to the wealth of the state. There are also many species of grasses that are weeds in lawns and cultivated fields, but the extent of their damage never has been, and probably never will be, correctly estimated.

The known species of grasses of the state have been listed by a number of authors, but the only paper devoted entirely to them was published by I. A. Lapham in 1857. Since then the number of species known to the state has increased nearly fifty percent. Some of these have been included in lists published since that time, but there are forty-three species which have not been listed before as occurring in the state. Some of these species have been introduced from Europe and Asia. Altogether two hundred and four species, representing sixty-three genera, have been listed in this publication.

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[1] This work was begun as a second minor under the direction of Professor William Trelease of the Department of Botany while the writer was working for the degree of doctor of philosophy in the University of Illinois. Professor Trelease urged the completion and publication of the work and has given every aid and encouragement during its progress. Mrs. Agnes Chase has also given valuable assistance, especially as regards questions of synonymy.

It has been the aim in this investigation to list all species of grasses which are known to have been collected in the state. Practically all specimens cited here have been seen by the author, and considerable pains have been taken to verify the determinations of the earlier botanists whose lists are cited in the bibliography.

In the preparation of this publication the grasses in the following herbaria have been studied:

University of Illinois Herbarium.—The collections in this herbarium have furnished the basis for the work. This herbarium includes partial collections of the earlier botanists Hall, Wolf, Vasey, M. S. Bebb, Mead, and Lapham, with the entire collections of Brendel, Schneck, Hill, Welsch, and Andrews. The collections of Dr. Welsch were not dated, but are known to have been made between 1862 and 1871. Mrs. Agnes Chase has presented a set of duplicates of her Illinois collections to the University, in addition to many other specimens. There are also duplicates of most of the species collected by Mr. V. H. Chase of Wady Petra, Illinois, which form an important part of the collection. With a very few exceptions the collections not mentioned in connection with other herbaria belong to the University of Illinois.

United States National Herbarium.—It was impossible during a brief visit to this herbarium to list all the Illinois specimens there, but only a few of the commoner species were omitted. All the specimens cited as collected by Skeels, Wilcox, and Hill are from this herbarium. There are duplicates of some of these in the Field Museum.

Field Museum Herbarium.—This herbarium contains a large number of Illinois specimens, and includes the herbarium of H. N. Patterson of Oquawka, besides smaller collections made by Sherff, De Selm, and others.

Northwestern University Herbarium.—The entire collection of H. H. Babcock belongs to this herbarium, together with specimens collected by Umbach, Shipman, and Smith.

Mr. Charles Robertson of Carlinville, Mr. Hallock Shearer of Mt. Carmel, Dr. H. S. Pepoon of Chicago, and Dr. G. H. French of Carbondale very kindly loaned Illinois specimens for examination, which have aided materially in this work. Some of the species furnished were not found in any of the herbaria examined.

This work would be quite incomplete without an expression of appreciation for the uniform kindness and many courtesies extended by the curators of these various herbaria. Special thanks are also due Professor William Trelease and Mrs. Agnes Chase for help in the solution of many puzzling problems.

The accompanying illustrations are all made from original drawings and are designed to show the most typical structure or structures of each species so that its identification will be as easy as possible. Spikelets in the same genus have been drawn, in nearly all cases, to the same scale; hence their relative size will be apparent from the figures.

The genera are arranged as in Gray's Manual, but the species under each genus are arranged alphabetically. The nomenclature follows the American code.

The bibliography includes only those works in which the grasses of the state are mentioned. For general information on grasses the reader is referred to "A Text-book of Grasses" by A. S. Hitchcock (Macmillan, 1914), which also contains an excellent bibliography. A recent publication of the Nebraska Experiment Station, "A Handbook of Nebraska Grasses," Bulletin 148, also contains a very complete bibliography.

The discussion of each species contains references to the articles or books cited in the bibliography. Thus, under *Sorghastrum nutans* (page 280), are given the synonyms to which the species was referred by earlier writers. "*Andropogon avenaceum,* Michaux '03, 58," then, refers us to "Flora Boreali-Americana," page 58, where this species was listed as *Andropogon avenaceum.*

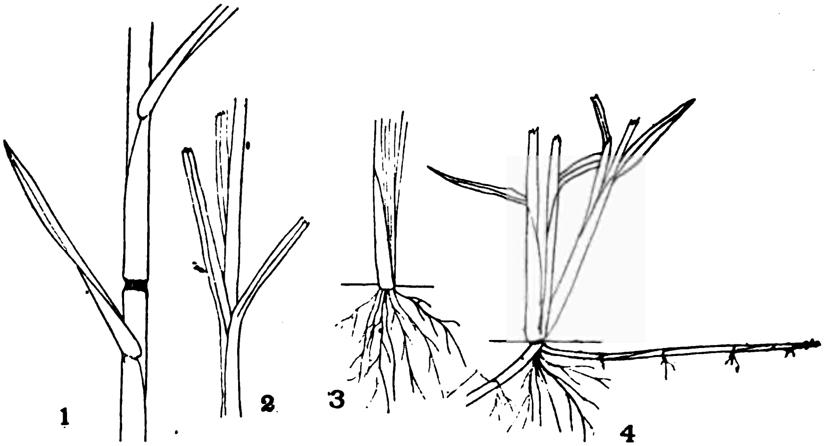
THE STRUCTURE OF GRASSES

Grasses belong to the family Poaceae, or Gramineae, which includes between three and four hundred genera. Sixty-three genera, exclusive of the cultivated grasses called grains, are found in Illinois. These genera include the two hundred and four species known to occur in the state.

There are few plants likely to be mistaken for grasses. The sedges resemble them most but are easily distinguished by their three-ranked leaves and solid stems (Fig. 2). Grasses have two-ranked leaves and usually hollow stems (except in Maydeae and Andropogoneae, of which Tripsacum and Andropogon are typical genera) (Fig. 1).

According to their length of life, grasses are classed as follows:

Annual Grasses.—Many species of grasses live but one year. The seeds of the preceding year germinate in spring or early summer and ripen seed in the summer and fall. Common crab grass, *Syntherisma sanguinalis,* old witch grass, *Panicum capillare,* and Indian corn, *Zea mays,* are well known examples of annual grasses.



Figs. 1–4.—1, Portion of grass culm showing 2-ranked leaves; 2, Portion of sedge culm showing 3-ranked leaves; 3, Portion of grass plant showing fibrous roots; 4, Portion of grass plant showing rootstocks

Winter Annuals.—In our latitude the seeds of certain annual grasses may germinate in the fall and live over winter in small tufts, sending up their flower stalks in early spring. These are known as winter annuals. Low spear grass, *Poa annua,* little barley, *Hordeum pusillum,* and the varieties of winter wheat are common examples of winter annuals.

Perennial Grasses.—These grasses are propagated both by seeds and by rootstocks. There are two types of perennial grasses in Illinois. In one (Fig. 3), the stem dies back to the base each winter and a new shoot comes up the next spring from a bud formed within the old sheath. These grasses have fibrous roots and form bunches or tufts, and for that reason are often called bunch grasses. Timothy, *Phleum pratense,* and orchard grass, *Dactylis glomerata,* are common examples of this type. In the other type (Fig. 4), the stem dies back to the base, but there are long, creeping rootstocks, or rhizomes, really underground stems, just below the surface of the soil, and the new shoots come from these. Such grasses usually form a compact sod, and hence many species are valuable for lawn grasses, as Kentucky blue grass, *Poa pratensis.* Other common grasses with creeping rootstocks are redtop, *Agrostis alba,* and couch grass, *Agropyron repens.* Besides these we have a single species of bamboo, the cane *Arundinaria macrosperma,* with woody, perennial culms.

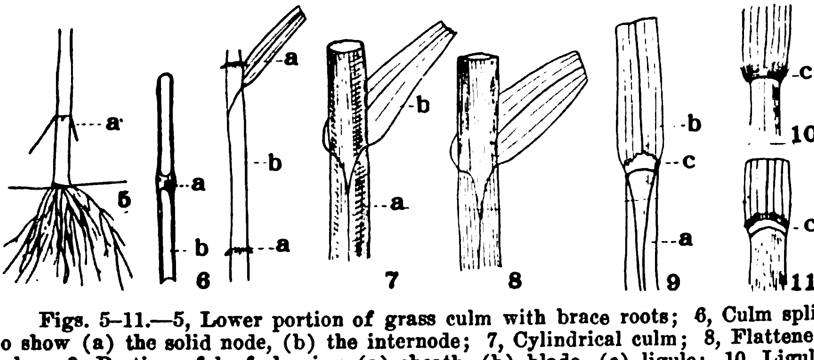
THE GRASS PLANT

The grass plant consists of root, stem, and leaves. The last two of these are modified to form the inflorescence.

Root.—The grass plant has slender, fibrous roots which are usually very numerous at the base of the plant (Fig. 3). In the corn plant and occasionally in other grasses, roots are developed from the lower nodes and act as prop, or brace roots (Fig. 5a).

Stem.—The stem of the grass plant is called a culm. In all but very young plants the culm is usually hollow except at the more or less swollen nodes (Fig. 6a). In maize and sorghum the stems are filled with pith. The parts of the culm between the nodes are called internodes (Fig. 6b). The culms are nearly always cylindrical, as in the corn stalk (Fig. 7), but they may be flattened, as in Canada blue grass, *Poa compressa* (Fig. 8). They are never three-angled, as in the sedges.

Leaf.—The leaves are borne at the nodes and consist of two parts, the sheath and the blade. The sheath (Figs. 7a and 9a) is wrapped



Figs. 5–11.—5, Lower portion of grass culm with brace roots; 6, Culm split to show (a) the solid node, (b) the internode; 7, Cylindrical culm; 8, Flattened culm; 9, Portion of leaf showing (a) sheath, (b) blade, (c) ligule; 10, Ligule a ring of hairs; 11, Ligule membranous, fringed with hairs

round the culm above the node; the blade (Figs. 7b and 9b) is the flat portion which extends free from the stalk and is often called the leaf. On the inner side of the joining of the blade and sheath is an appendage called the ligule (Fig. 9c). This is usually thin and membranous (Fig. 9c) but sometimes consists of a row of fine hairs (Fig. 10c), or it may be a thin membrane fringed with hairs (Fig. 11c).

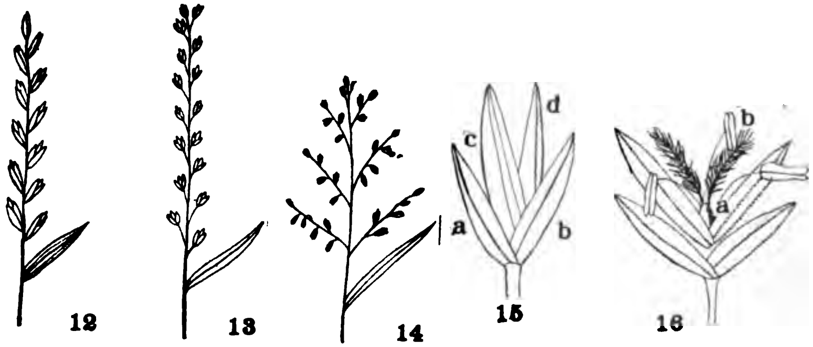
The edges of the sheath are grown together in most species of *Bromus* and *Festuca,* and in some other genera. Sometimes the sheaths become very much inflated and inclose the inflorescence, as in *Andropogon virginicus* (Fig. 24). Some species of water grasses have inflated sheaths which act as floats, as in *Paspalum repens* (Fig. 36).

The blades are usually linear and very much longer than they are wide (Fig. 37), but in *Panicum boscii* (Fig. 91) and some other species, the blades are quite broad as compared with the length. The blade has a strong midrib and several nerves, or veins, on each side, which are parallel to the midrib except in the broad-leaved species. There are short appendages called auricles at the base of the blade in some grasses. These are prominent on the leaves of wheat and barley. They are also found in Hordeum and Agropyron, and other genera closely related to these.

THE INFLORESCENCE, OR FLOWER CLUSTER

The flowers of grasses are small and inconspicuous but are closely grouped together and borne on shoots that are easily distinguished from the leaves. The various bracts which make up the flower are modified leaves. In some species of grasses the perfect flowers, from which the seeds are formed, are hidden by the sheaths, as in the case of some species of Panicum and in certain other genera.

There are three common forms of inflorescence—the spike, the raceme, and the panicle. The inflorescence is made up of spikelets,



Figs. 12–16.—12, Spike; 13, Raceme; 14, Panicle; 15, Spikelet, (a) first glume, (b) second glume, (c) lemma, (d) palea; 16, Spikelet opened to show (a) pistil, (b) stamens

which are single flowers or groups of flowers subtended by a pair of bracts (Figs. 15a and b) called glumes.

The Spike.—The spike has a long, unbranched axis, with the spikelets sessile, or without stalks (Fig. 12). Wheat, *Triticum vulgare,* and couch grass, *Agropyron repens,* are common examples of this type.

The Raceme.—This type of inflorescence (Fig. 13) differs from the spike in having stalked, or pediceled spikelets. A typical example is the simple form of meadow fescue, *Festuca elatior.* Often the pedicels of the spikelets are very short and the inflorescence has the general appearance of a spike and is called a spike-like raceme. Syntherisma (Fig. 29), Paspalum (Fig. 37), and Andropogon (Fig. 21) are examples of spike-like racemes.

The Panicle.—In the panicle (Fig. 14) the main axis of the inflorescence is branched and rebranched, and the spikelets are pediceled. The common oat, *Avena sativa,* and Kentucky blue grass, *Poa pratensis,* are good examples of this type of inflorescence. Sometimes the branches of a panicle are so short that they are hidden by the spikelets and the inflorescence appears to be a spike. *Heleochloa schoenoides* (Fig. 148) and canary grass, *Phalaris arundinacea* (Fig. 117), are familiar examples. The axis of an inflorescence is usually known as a rachis. In some grasses, as, for example, squirrel-tail grass, *Hordeun jubatum,* the axis disjoints at the nodes at maturity.

A perfect flower contains both stamens and pistils. Most grasses bear perfect flowers, but following are a few exceptions to the rule:

Dioecious Plants.—There are some species of grasses in which the pistillate spikelets are on one plant and the staminate on another. A few examples of this type of inflorescence are found among Illinois grasses. *Eragrostis hypnoides* is one of these, the lemmas of the pistillate spikelets being slightly narrower and more pointed than those of the staminate spikelets.

Monoecious Plants.—In these plants the staminate and pistillate spikelets are on different parts of the same inflorescence, or on different parts of the plant. In wild rice, *Zizania palustris* (Fig. 107), the staminate flowers are on the lower branches of the panicle and the pistillate spikelets on the upper. *Tripsacum dactyloides* (Fig. 17) has the staminate spikelets at the end of the spikes and the pistillate spikelets embedded in the basal portion. In the corn plant the ear is the pistillate inflorescence and is borne on a different part of the plant from the tassel, which is the staminate inflorescence.

In Andropogon, Sorghastrum, and other genera closely related there are staminate, pistillate, or sometimes sterile spikelets, as well as perfect flowers in the same inflorescence. The first three types are often referred to merely as imperfect spikelets. These spikelets have a definite arrangement (Figs. 22 and 28). Sterile spikelets have neither stamens nor pistils and are often very much reduced so that only the stalk, or pedicel, remains (Fig. 27).

THE SPIKELET

The spikelet may consist of a single flower or of a number of flowers. As the classification of grasses is based primarily on the characters of the spikelet, it is essential to know something of its structure.

The stalk of the spikelet is known as the pedicel. The spikelet consists of a short axis, called the rachilla, which bears one or more flowers. The rachilla may be jointed to the pedicel either above or below the glumes.

The Glumes.—At the base of the spikelet are two empty bracts, which are called glumes. They are designated as the first, or outer glume (Fig. 15a), and the second, or inner glume (Fig. 15b). They are usually easily distinguished from the other parts of the spikelet by the difference in shape, texture, number of nerves, amount of hairs present, etc. Sometimes the first glume is very small, as in ***Syntherisma sanguinalis*** (Fig. 32), or it may be wanting, as in the species of Paspalum (Fig. 41). Both glumes are absent in Homalocenchrus (Fig. 108). Sometimes the glumes are awned, as in ***Elymus canadensis*** (Fig. 280).

The Lemmas.—The lemmas are the bracts of the spikelet found within and above the glumes (Fig. 15c). Their number varies with the number of flowers found in the spikelet. There is usually a flower at the base of each lemma; if the flower is sterile, the lemma is called a sterile lemma. The lemma often differs from the glumes in texture, being sometimes much thinner, and sometimes, as in Panicum, much hardened. It is often awned (Fig. 147); the awns are sometimes spirally twisted or bent (Figs. 124 to 133).

The Palea.—The palea (Fig. 15d) together with the lemma serves to inclose the stamens and pistil. It is usually two-nerved and like its lemma in texture.

The Stamens.—There are usually three stamens (Fig. 16b), but the number varies from one to six.

The Pistil.—In our species there is a single pistil (Fig. 16a), which has a one-celled ovary, two styles (rarely one), and two feathery stigmas.

The Fruit.—The grass seed, so-called, is in reality a fruit (a caryopsis), the seed being inclosed in the ripened ovary.

KEY TO THE GENERA OF ILLINOIS GRASSES

a. Inflorescence in a single terminal symmetrical (not one-sided) spike, the spikelets 2- to several-flowered, sessile on the main axis, single or 2 or 3 at each joint (as in wheat, barley, or rye).

b. Axis disjointing with spikelets attached; spikelets 3 together at each joint, the lateral ones sterile and reduced to awns (barley). 60. *Hordeum*

bb. Axis not disjointing; spikelets 1 to 3 at each joint, all alike.

c. Spikelets 2 or 3 at each joint of the axis; glumes in front of the spikelet, awl-shaped, not keeled. 61. *Elymus*

cc. Spikelets 1 at each joint of the axis; glumes at the sides of the spikelets.

d. Spikelets placed edgewise on the axis, the inner glume wanting except on the terminal spikelet. 58. *Lolium*

dd. Spikelets placed flat against the axis.

e. Glumes obsolete or rudimentary; spikelets horizontally spreading at maturity. 62. *Hystrix*

ee. Glumes well developed; spikelets appressed to the axis.

f. Glumes broadly ovate, abruptly awned or pointed, sometimes toothed; plants annual (wheat). *Triticum*

ff. Glumes lanceolate, or narrower, awned or awnless, not toothed.

g. Lemmas prickly-hispid on the keel; glumes 1-nerved, narrow; plants annual (rye). *Secale*

gg. Lemmas smooth on the keel; glumes several-nerved; plants perennial. 59. *Agropyron*

aa. Inflorescence a panicle, raceme, or aggregation of spikes; panicle may be open, as in oats, or contracted, as in timothy; racemes usually appear like spikes, but some of the spikelets are pediceled, as Paspalum (Fig. 37), Andropogon (Fig. 23), and crab grass (Fig. 29); the spikes are one-sided and aggregate, as in Bermuda grass (Fig. 193).

b. Fruit a bur with barbed spines. 12. *Cenchrus*

bb. Fruit not a bur.

c. Spikelets unisexual, the staminate and pistillate in different parts of the same inflorescence or in different inflorescences.

d. Pistillate spikelets in ears in the axils of the leaves; staminate spikelets in a terminal tassel (corn). *Zea*

dd. Pistillate and staminate spikelets in different parts of the same inflorescence.

e. Inflorescence consisting of 1 to 4 stout spikes, the lower part thick and hard, readily disjointing, the pistillate spikelets embedded in the joints, the staminate spikelets in pairs along the narrow axis of the upper part. 1. *Tripsacum*

ee. Inflorescence a large terminal panicle, the pistillate spikelets erect on the ascending upper branches of the panicle, the staminate pendulous on the spreading lower branches. 13. *Zizania*

cc. Spikelets perfect; or perfect and staminate, or sterile, arranged in pairs (unisexual in *Eragrostis hypnoides*, but the spikelets alike in appearance).

d. Spikelets in pairs, one perfect and sessile, the other pediceled and staminate (rarely perfect) or sterile (apparently two pediceled spikelets in Holcus and Sorghastrum), on a jointed axis, readily disjointing with the spikelets attached; glumes hardened; spikelets dorsally compressed, the sessile spikelets awned.

e. Inflorescence of slender racemes, these single or 2 or 3 together, not panicled. 3. *Andropogon*

ee. Inflorescence an open or contracted panicle.

f. Panicle densely wooly, of slender, many-flowered racemes; spikelets all perfect. 2. *Erianthus* ff. Panicle not wooly, joints more or less short pubescent; racemes of 1 to 5 joints, pediceled spikelet staminate or reduced to the pedicel.

g. Pediceled spikelets staminate; panicle open; awns deciduous. 5. *Holcus*

gg. Pediceled spikelets reduced to a hairy pedicel; panicle narrow; awns persistent. 4. *Sorghastrum*

dd. Spikelets not in pairs, or if so, the two alike; axis not disjointing.

e. Spikelets sessile in 1-sided spikes, these digitate or racemose on a common axis (as in Bermuda grass, Fig. 193).

f. Spikes digitate (Fig. 201).

g. Spikes slender; spikelets 1-flowered; plants perennial. 40. *Capriola*

gg. Spikes stout; spikelets 3- or 4-flowered; plants annual.

h. Rachis of spike prolonged into a point beyond the spikelets; lower lemmas awn-tipped. 43. *Dactyloctenium*

hh. Rachis of spike not prolonged beyond the spikelets; lemmas awnless. 44. *Eleusine*

ff. Spikes racemose (Figs. 194, 195, 196).

g. Spikes very slender; spikelets remote, closely appressed; plants annual. 41. *Schedonnardus*

gg. Spikes thick; spikelets densely imbricated.

h. Plants robust, 4 to 6 feet tall; spikelets 1-flowered; first glume exceeding the floret, stiffly ciliate on the keel; spikelets falling entire. 39. *Spartina*

hh. Plants not robust, not over 3 feet tall; spikelets with 1 perfect floret and 1 or 2 sterile lemmas; first glume shorter than the floret, persistent after the fall of the floret. 42. *Bouteloua*

ee. Spikelets pediceled, in open (Fig. 118) or spike-like (Fig. 117) panicles, or in racemes (Fig. 29).

f. Spikelets 1-flowered or with 1 perfect terminal floret and 1 or 2 sterile or staminate florets below it.

g. Spikelets without staminate or rudimentary florets below the perfect one; spikelets laterally compressed, glumes keeled.

h. Glumes wanting; spikelets strongly flattened, imbricate on the slender branches of an open panicle; lemmas awnless. 14. *Homalocenchrus*

hh. Glumes present, if minute the lemmas awned.

i. Lemmas more or less indurate, at least firmer than the glumes, terete or subterete, not keeled.

j. Lemma not sharp-pointed, strongly indurate; panicle branches spreading or drooping. 17. *Milium*

jj. Lemma sharp-pointed or awned; panicle branches ascending or erect.

k. Awn 3-parted; lemma with a sharp-pointed callus at base. 20. *Aristida*

kk. Awn simple.

l. Awn 4 to 8 inches long, twisted and bent; lemma with a needle-pointed callus. 19. *Stipa*

ll. Awn not over 2 inches long; callus not sharp-pointed.

m. Awn deciduous, bent; lemma broad, elliptical or ovate. 18. *Oryzopsis* mm. Awn, if present, persistent; lemmas lanceolate.

n. Glumes minute or obsolete; rachilla prolonged beyond the base of the palea; floret stipitate. 22. *Brachyelytrum*

nn. Glumes usually at least half as long as the spikelet (minute in *M. schreberi*); rachilla not prolonged; floret not stipitate. 21. ***Muhlenbergia***

ii. Lemmas not indurate, at least not firmer than the glumes, or if somewhat firmer, strongly compressed and keeled.

j. Panicle compact, cylindrical; spikelets strongly flattened and keeled.

k. Spikelets about 1 cm. long; floret conspicuously hairy at base; robust perennial with stout, scaly rootstocks. 30. *Ammophila*

kk. Spikelets not over 4 mm. long; lemma not hairy at base; plants without rootstocks.

l. Panicle partly included in a broad subtending sheath; glumes shorter than the lemma. 23. *Heleochloa*

ll. Panicle not included in a subtending sheath; glumes not shorter than the lemma.

m. Glumes abruptly aristate, stiffly ciliate on the keel; lemmas awnless (timothy). 24. *Phleum*

mm. Glumes not pointed nor ciliate on the keel; lemma with a slender awn from the back. 25. *Alopecurus*

jj. Panicle open or contracted; spikelets not strongly flattened.

k. Floret conspicuously hairy at base.

l. Lemma with a delicate dorsal awn; rachilla prolonged beyond the base of the palea. 29. *Calamagrostis*

ll. Lemma awnless; rachilla not prolonged. 28. *Calamovilfa*

kk. Floret not hairy at base.

l. Lemma shorter than the glumes; palea usually wanting. 27. *Agrostis*

ll. Lemma longer than the glumes or as long; palea present.

m. Florets stipitate; lemma with a minute awn; panicle drooping. 31. *Cinna* mm. Florets not stipitate; lemma awnless; panicle not drooping. 26. *Sporobolus*

gg. Spikelets with 1 or 2 staminate or rudimentary florets below the perfect one (first glume wanting in Paspalum and in some species of Syntherisma, the sterile lemma simulating a second glume).

h. Spikelets laterally compressed; glumes strongly keeled; sterile florets falling attached to the perfect floret.

i. Plants grayish-velvety thruout; one floret below the perfect one, staminate; perfect floret with a hooked awn on the back. 32. *Notholcus*

ii. Plants glabrous thruout; two florets below the perfect one.

j. Panicle open; lower florets staminate; plants fragrant. 16. *Torresia*

jj. Panicle contracted or spike-like; lower florets reduced to minute scales. 15. *Phalaris*

hh. Spikelets dorsally depressed; glumes not keeled; spikelets falling entire; fertile floret indurate.

i. Spikelets subtended by 1 to several slender bristles, in a narrow spike-like panicle. 11. *Chaetochloa*

ii. Spikelets not subtended by bristles.

j. Spikelets subsessile along one side of a slender axis; first glume obsolete or minute.

k. Racemes subdigitate; fruit subindurate with a flat, white, hyaline margin; spikelets compressed, biconvex; annuals. 6. *Syntherisma*

kk. Racemes solitary or racemose; fruit indurate, the firm margin inrolled; spikelets plano-convex; first glume obsolete; perennials. 8. *Paspalum*

jj. Spikelets in open or compact panicles.

k. Floret subindurate; margins of lemma hyaline, flat. 7. *Leptoloma*.

kk. Floret strongly indurate; margins of lemma firm, inrolled, at least at base.

l. Sterile lemma awned or strongly mucronate; fruit pointed; spikelets short-pediceled in clusters; coarse annuals. 10. *Echinochloa*

ll. Sterile lemma awnless; fruit not pointed; spikelets usually long-pediceled. 9. *Panicum*

ff. Spikelets 2- to many-flowered; sterile florets. if any, above the perfect ones (except in Uniola, Fig. 227).

g. Glumes exceeding or equaling the florets (except in Sphenopholis and Koeleria; in these at least the second. glume is usually longer than first floret), usually papery and shining.

h. Spikelets at least 8 mm. long.

i. Florets 2 to 4, awned from the back (awn rudimentary in cultivated oats).

j. Panicle narrowly pyramidal; spikelets 8 to 10 mm. long, not pendulous. 37. ***Arrhenatherum***

jj. Panicle about as broad as long; spikelets 2 cm. long or more, pendulous (oats). 36. ***Avena***

ii. Florets 7 to 12, awned from between the teeth of a bidentate apex. 38. ***Danthonia***

hh. Spikelets not over 5 mm. long.

i. Lemmas bearing delicate dorsal awns; panicle branches capillary, flexuous. 35. ***Deschampsia***

ii. Lemmas awnless, or obscurely awn-tipped.

j. Glumes dissimilar, the second broadly wedge-shaped or obovate; spikelets falling entire. 33. ***Sphenopholis***

jj. Glumes similar, acute, persistent after the fall of the florets. 34. ***Koeleria***

gg. Glumes shorter than the lowest floret.

h. Culms woody perennial; plants shrubby; blades narrowed into a short petiole above the sheath. 63. ***Arundinaria***

hh. Culms herbaceous; plants not shrubby; blades sessile on the sheath.

i. Plants usually 6 to 12 feet tall, the culms strong, reed-like, with stout, creeping rootstocks; panicle large, feathery at maturity. 46. ***Phragmites***

ii. Plants rarely 5 feet tall, the culms not reed-like; panicle not feathery.

j. Lemmas 3-nerved.

k. Spikelets short-pediceled along one side of a slender rachis, forming elongate racemes, these arranged in a rather open panicle. 45. ***Leptochloa***

kk. Spikelets not in 1-sided racemes.

l. Lemmas glabrous, not lobed; nerves not excurrent. 49. ***Eragrostis***

ll. Lemmas hairy on the nerves below, lobed at the apex; midnerve excurrent.

m. Panicle usually large, spreading; lateral nerves of the lemmas excurrent; palea not fringed. 47. ***Tridens***

mm. Panicle small, few-flowered; lateral nerves of the lemmas not excurrent; palea conspicuously fringed. 48. ***Triplasis***

jj. Lemmas 5- to many-nerved (the intermediate obscure in *Poa alsodes*).

k. Upper floret unlike the lower, folded together forming a club-shaped mass; spikelets pendulous, falling entire. 50. ***Melica***

kk. Upper florets like the lower; spikelets sometimes drooping, not pendulous.

l. Lemmas firm, somewhat hardened, faintly many-nerved, acuminate.

m. Lower florets empty but like the upper in appearance; spikelets strongly flattened; lemmas not polished; panicle drooping. 52. *Uniola*

mm. Lower florets perfect; spikelets not flattened, florets turgid, polished; grain at maturity beaked, expanding the lemma and palea. 51. *Diarina*

ll. Lemmas herbaceous, 5- to 9-nerved, the nerves usually strong.

m. Spikelets strongly flattened, densely crowded in 1-sided clusters at the ends of the stiff, naked panicle branches. 53. *Dactylis*

mm. Spikelets not flattened, nor in 1-sided clusters.

n. Lemmas keeled, and usually with a tuft of cobwebby, white hairs at base (bluegrass). 54. *Poa*

nn. Lemmas not keeled, rounded on the back, not cobwebby at base.

o. Lemmas obtuse, usually scarious at the tip; nerves parallel, usually prominent. 55. *Panicularia*

oo. Lemmas acute or awned; nerves approaching at the apex.

p. Lemmas not toothed, awned from the tip or awnless: spikelets not over 15 mm. long, usually less. 56. *Festuca*

pp. Lemmas minutely 2-toothed, usually awned from just below the apex; spikelets rarely less than 2 cm. long. 57. *Bromus*

DESCRIPTIONS AND DISTRIBUTION OF ILLINOIS GRASSES

1. TRIPSACUM L.

This is a subtropical genus of which one species is found in southern Illinois. It includes tall, coarse perennials with creeping rootstocks. The inflorescence consists of solitary or clustered spikes borne at the ends of the culms or their branches. There are two kinds of spikelets in each spike, the pistillate spikelets borne singly, sunken in the thickened axis of the lower part, and the staminate in pairs on the slender upper part. The lower part of the axis is very hard and woody, and separates readily into joints. In each of these joints is embedded a pistillate spikelet, which has a very hard outer glume. The upper part of the stalk is slender, not woody, and does not separate into joints, but falls off entire.

Tripsacum dactyloides L.

Gama Grass. Sesame Grass (Fig. 17)

Michaux '03, 60; Lapham '57, 548, 598; Patterson '76, 52; Flagg '78, 284; Brendel '87, 89.

Entire plant smooth and glabrous; culms 3 to 7 feet tall; leaves 3 dm. or more long, 1 to 3.5 cm. wide; ligule a fringe of hairs less than 1 mm. long; spikelets 8 mm. long.

This is one of the largest grasses found in the state. It prefers moist soil in swamps or along ditches and streams. It is an excellent forage grass.

ILLINOIS SPECIMENS: Without locality, southern Illinois, *Vasey*. CHRISTIAN CO., Taylorville, *Andrews*. HANCOCK CO. Without locality, *Mead* in 1843. MACOUPIN CO. Macoupin, *Robertson*, July, 1884. MARION CO. Without locality, *M. S. Bebb*, 1860. ST. CLAIR CO. Mascoutah, *Welsch*. WABASH CO. Without locality *Schneck, July*, 1890; without locality, *Shearer*.

2. ERIANTHUS Michx.

Wooly Beard Grass

This genus is found in both temperate and tropical regions. The plants are tall, reed-like perennial grasses with thick, creeping rootstocks. One species is cultivated for ornament, and is commonly known as plume grass, wool grass, or hardy pampas grass. The inflorescence is a large, compact panicle clothed with long, silky hairs, which are borne on the panicle branches and in a tuft at the base of each spikelet. The spikelets are in pairs, one pediceled, the other sessile, but both are perfect, of equal size, and bear long awns.

Erianthus divaricatus (L.) Hitchc.

Spiral-awned Plume Grass (Figs. 18 and 19)

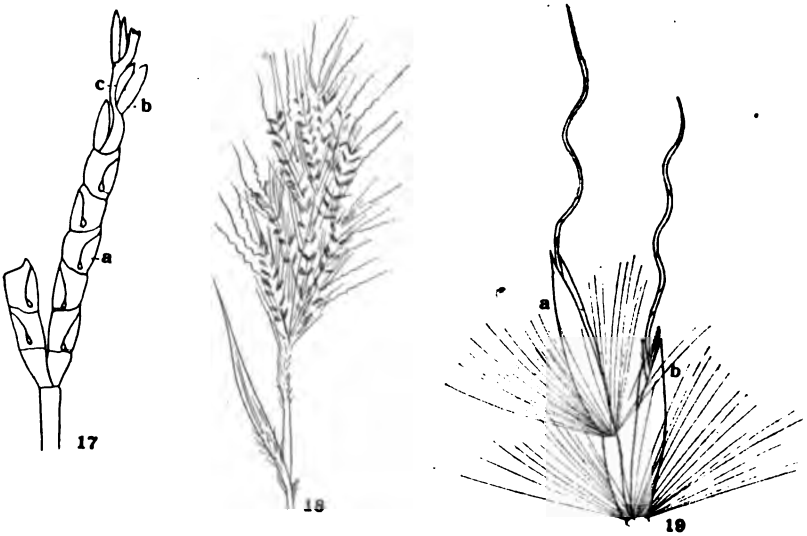
Erianthus alopecuroides, Lapham '57, 548, 599; Patterson '76, 52; Flagg '78, 285. *E. saccharoides*, Brendel '87, 89.

Culms 3 to 8 feet tall, with appressed hairs at the nodes and on the upper portion near the inflorescence; leaves long, one-half inch to one inch wide; panicle loose, with soft, silky hairs.

This grass was probably once found in the southern part of the state, but it is doubtful if it occurs in the state at the present time.

JACKSON CO. Without locality, *French*, Sept., 1878.

Erianthus contortus Baldwin.—This species is described by Lapham among the plants of Illinois, but no citations are given. As it is not mentioned by any other author, and no specimens have been seen, it is extremely doubtful if it has ever been collected in Illinois.



Figs. 17–19.—17, *T. dactyloides*, part of inflorescence: (a) pistillate spikelet, (b) and (c) staminate spikelets; 18, *E. divaricatus*, inflorescence; 19, *E. divaricatus*, pair of spikelets: (a) pediceled spikelet, (b) sessile spikelet

3. ANDROPOGON L.

Beard Grass

These grasses are tall, often coarse, tufted perennials, found in both temperate and tropical climates. The inflorescence is of lateral and terminal spikes, with paired spikelets. One spikelet is sessile and perfect, usually bearing a twisted awn; the other is pediceled, imperfect, either bearing stamens or reduced to a single glume, which is often minute or entirely lacking. The rachis joints and pedicels often bear long, silky hairs. The leaves are long and narrow, the ligules short and membranous, with fringed edges. The culms in some of the species show a conspicuous bluish bloom, particularly in the region of the nodes, hence the common name bluestem.

a. Inflorescence protruding from a very prominent spathe, which is shorter than, or equaling the inflorescence; awns straight, usually three times the length of the sessile spikelets; pediceled spikelets reduced to a minute scale or wanting; rachis joints very slender. *A. virginicus*

aa. Inflorescence not protruding from a prominent spathe; awns more or less bent, usually less than twice the length of the sessile spikelet; pediceled spikelets always present and distinct; rachis joints thickened, clavate.

  b. Inflorescence of paired or digitate spikes; pediceled spikelet nearly as long as the sessile, the pedicel thickened and somewhat clavate. *A. furcatus*

  bb. Inflorescence of solitary spikes; pediceled spikelet very much shorter than the sessile, the pedicel thin and straplike. *A. scoparius*

Andropogon furcatus Muhl.

Forked Beard Grass. Big Bluestem (Figs. 20 and 21)

Lapham '57, 548, 599 (Plate 4, Fig. 6); Patterson '76, 52; Flagg '78, 285; Brendel '87, 64; Higley and Raddin '91, 140; Huett '98, 129; Gleason '07, 181; Gleason '10, 147; Gleason, '12, 48; Gates '12, 354.

Culms smooth, 3.5 to 6 feet tall; sheaths smooth, blades rough on the margins; spikes stout, usually purplish; pediceled spikelet usually staminate, 6 to 7 mm. long; sessile spikelet 8 to 9 mm. long, the awn 10 to 14 mm. long, spirally twisted and usually bent.

A common grass in Illinois, characteristic of the prairie, but found in many other situations. It furnishes good pasture when young, but the stems soon become hard.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Without locality, along railroad track, *Gibbs*, Oct., 1878; Without locality, *Percival*, Oct., 1876; Champaign, *Mosher*, Sept., 1913; Savoy, *Gibbs*, Sept., 1898; Seymour, *Tsou*, Oct., 1913; Rantoul, *Gates*, Oct., 1907. CHRISTIAN CO. Taylorville, *Andrews* in 1898. COOK CO. Chicago, *Sherff*, Sept., 1912; Mayfair, Chicago, *Gates*, Sept., 1905; South Chicago, *Schneck*, Aug., 1893. FORD CO. Near Roberts, *Wilcox*, July, 1902. FULTON CO. Without locality, *Pepoon;* Canton, *Wolf*. JO DAVIESS CO. Without locality, *Pepoon* 443. LAKE CO. Beach area near Waukegan, *Gates* in 1908; Waukegan, *Gleason* and *Shobe* 323. MCHENRY CO. Algonquin, *Nason*, July, 1878. MACOUPIN CO. Carlinville, *Robertson*, Aug., 1882. MENARD CO. Athens, *Hall*, 1861. OGLE CO. Oregon, *Waite*, Aug., 1885. PEORIA CO. Peoria, *McDonald*, Aug., 1894; Peoria, *Brendel;* Glasford, *Wilcox*, July, 1902. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase*, Sept., 1897. WABASH CO. Without locality, *Schneck*, Nov., 1900; without locality, *Shearer;* Shannon's swamp, *Schneck*, Oct., 1882; Hanging Rock, *Schneck*, Sept., 1878; Lucas farm, *Schneck*, Aug., 1900. WILL CO. Joliet, *Skeels*, Aug., 1904.

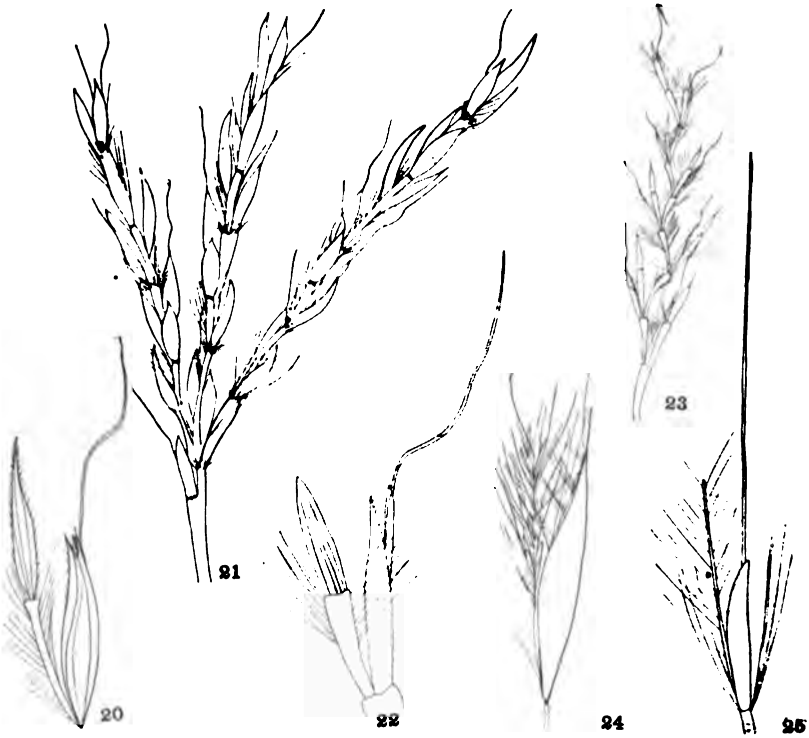
Andropogon scoparius Michx.

Broom Beard Grass. Little Bluestem (Figs. 22 and 23)

Engelmann '44, 104; Lapham '57, 549, 599; Patterson '76, 52; Flagg '78, 285; Brendel '87, 64; Higley and Raddin '91, 140; Huett '97, 129; Gleason '07, 181; Gleason '10, 147; Gates '12, 354.

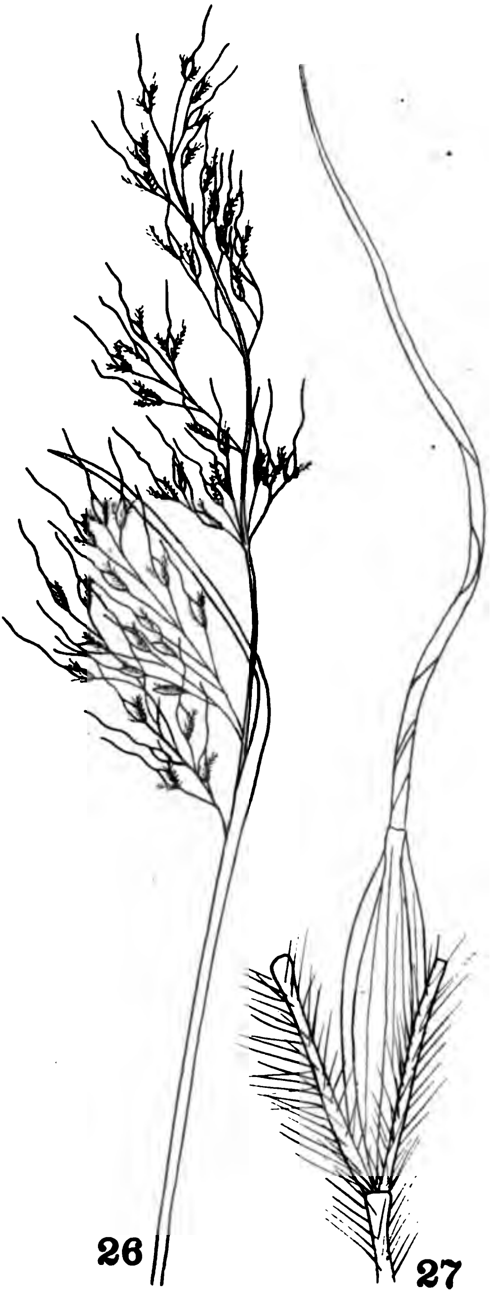
Culms smooth or slightly pubescent, 1 to 4 feet tall; leaves slightly rough; spikes slender; pediceled spikelet a single, small, awn-pointed glume; sessile spikelets 6 to 7 mm. long, the awn spirally twisted and bent.

A common prairie grass, easily distinguished from *A. furcatus* by its habit of growing in closer bunches. It is also much shorter and more slender, and has a tendency to grow more on hills or ridges, while *A. furcatus* likes more level, richer soil. These two species of Andropogon were found in abundance on the original prairie. This species usually turns purple early in the season. When young it is relished by stock.



Figs. 20–25.—20, *A. furcatus*, pair of spikelets; 21, *A. furcatus*, inflorescence; 22, *A. scoparius*, pair of spikelets; 23, *A. scoparius*, inflorescence; 24, *A. virginicus*, inflorescence; 25, *A. virginicus*, pair of spikelets

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Without locality, along railway track, *Gibbs*, Oct., 1898; Champaign, *Clinton*, Oct., 1895. CHRISTIAN CO. Taylorville, *Andrews*. COOK CO. Constance, Chicago, *A. Chase*, Aug., 1900; Englewood, *Hill*, Sept., 1875; Chicago, *Sherff*, Aug., 1912; Thornton, *Hill*, July, 1865. FULTON CO. Without locality, *Pepoon*. JACKSON CO. Makanda, *Seymour*, Aug., 1880. JO DAVIESS CO. Without locality, *Pepoon* 443; Hanover, *Gleason* and *Gates* 2528. KANKAKEE CO. Altorf, *Hill*, Aug., 1872; Waldron, *Hill*, Aug., 1873; Kankakee, *De Selm*, Sept., 1913. LAKE CO. Beach area north of Waukegan, *Gates* 2921; Waukegan, *Gleason* and *Shobe* 319. MCHENRY CO. Ringwood, *Vasey*. MACOUPIN CO. Carlinville, *Robertson*, Aug., 1880. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald*, Sept., 1894. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase* 126. WABASH CO. Without locality, *Shearer;* Walter's farm, *Schneck*, Sept., 1900; Mt. Carmel, *Schneck*, Oct., 1876; Old Palmyra, *Schneck*, Sept., 1900; Hanging Rock, *Schneck*, Sept., 1904.



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Figs. 26–27.—26, *S. nutans*, inflorescence; 27, *S. nutans*, group of spikelets

Andropogon virginicus L.

Virginia Beard Grass. Broom Sedge (Figs. 24 and 25)

Andropogon virginicus, Lapham '57, 549, 599; Patterson '76, 53; Flagg '78, 285. *A. dissitiflorus,* Brendel '87, 89. *A. virginicus,* Higley and Raddin '91, 140.

Culms smooth or sparsely pubescent, 1.5 to 4 feet tall; leaves usually smooth; spikes slender, 2, 3, or more inclosed in a prominent spathe; pediceled spikelets reduced to a minute scale, or only the pedicel present; sessile spikelets 3 to 4 mm. long, the awns very long and straight.

This grass grows best in rather sterile soil. It is often looked upon as a weed because it forces more valuable plants from permanent pastures, tho it furnishes fairly good grazing early in the season.

COOK CO. Evanston, *Shipman,* Sept., 1875. FULTON CO. Without locality, *Pepoon.* ST. CLAIR CO. Without locality, *Brendel,* 1850; Mascoutah, *Welsch.* WABASH CO. Without locality, *Schneck;* without locality, *Shearer;* Mt. Carmel, *Schneck,* Oct., 1876; Walter's farm, *Schneck,* Oct., 1900; Simond's farm, *Schneck,* Oct., 1897.

4. **SORGHASTRUM** Nash

This genus is closely related to Andropogon, but has the spikelets in panicles. It is found in both tropical and temperate climates. The spikelets are in pairs or in threes at the ends of the panicle branches and are of two kinds, a sessile perfect spikelet with one or two slender, hairy pedicels, the sterile spikelet obsolete.

Sorghastrum nutans (L.) Nash

Indian Grass. Wood Grass. Wild Sorghum (Figs. 26 and 27)

Andropogon avenaceum, Michaux '03, 58. *Sorghum nutans,* Lapham '57, 549, 601 (Plate 4, Fig. 7); Patterson '76, 53; Flagg '78, 285. *Chrysopogon nutans,* Brendel '87, 64; Higley and Raddin '91, 141; Huett '97, 129. *Sorghastrum avenaceum,* Gleason '07, 181. *Sorghastrum nutans,* Gleason '10, 147; Gleason '12, 48; Gates '12, 354.

Culms smooth, 3 to 6 feet tall; leaves long and narrow, the blades slightly rough; ligule membranous, 3 to 5 mm. long, the edge slightly fringed; spikelets 6 to 8 mm. long, pubescent, especially at base, the awn loosely twisted, 12 to 15 mm. long.

This grass is perennial by long, creeping rootstocks. It was one of the grasses of the original prairie and was found over practically the same area as *Andropogon furcatus.* When in bloom it is one of the most beautiful of our native grasses, with its graceful bronze-colored panicles and bright yellow anthers.

ILLINOIS SPECIMENS: Without locality, Vasey. CHAMPAIGN CO. Without locality, *Searle,* Oct., 1876; Urbana, *Clinton,* Aug., 1895; Champaign, *Gibbs,* Oct., 1898; Champaign, *Clinton,* Aug., 1898. CHRISTIAN CO. Taylorville, *Andrews.* COOK CO. Chicago, *A. Chase,* Aug., 1901. DU PAGE CO. Hinsdale, *Smith,* Oct., 1902. FULTON CO. Without locality, *Pepoon;* Canton, *Wolf.* JO DAVIESS CO. E. of Warren, *Pepoon* 562. KANKAKEE CO. Kankakee, *De Selm,* Sept., 1913. LAKE

CO. Beach area north of Waukegan, *Gates* 2966; Waukegan, *Gleason* and *Shobe* 325. MACOUPIN CO. Carlinville, *Robertson*, Aug., 1880. MARSHALL CO. Near Lawn Ridge, *V. H. Chase* 1591. PEORIA CO. Peoria, *McDonald;* Peoria, *Brendel.* ST. CLAIR CO. Mascoutah, *Welsch.* VERMILION CO. Muncie, *Mosher*, Oct., 1915. WABASH CO. Without locality, *Schneck*, Oct., 1900; without locality, *Shearer;* Old Palmyra, *Schneck*, Sept., 1879. WILL CO. Joliet, *A. H. Skeels*, Sept., 1904. WINNEBAGO CO. Fountaindale, *M. S. Bebb.*

5. HOLCUS L.

These grasses belong to tropical and warm temperate climates and are natives of the Old World. The various cultivated sorghums belong to this genus, also kaffir corn and broom corn. One species, *H. halapensis*, is naturalized in America and has been found as a weed in Illinois. The inflorescence consists of a large open panicle, the pediceled spikelets staminate.

Holcus halapensis L.

Johnson Grass (Fig. 28)

Sorghum halapense, Gray's Manual, 7th ed., Britton '07.

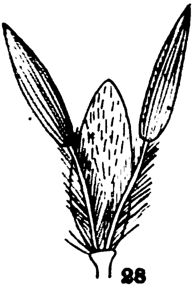

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Fig. 28.—*H. halapensis*, group of spikelets

Culms 3 to 5 feet tall, usually smooth; leaves almost smooth, somewhat rough on the margins; ligule membranous, 2 mm. long, the upper half fringed; spikelets in twos or threes; perfect spikelets about 5 mm. long, with appressed hairs, awn 10 to 16 mm. long; pediceled spikelets slightly longer than the sessile.

This grass is perennial by long, stout, creeping rootstocks and is very difficult to eradicate where it once becomes established. It is much liked by stock, but under certain conditions is poisonous thru the production of hydrocyanic acid.

CHAMPAIGN CO. Urbana, *Mosher*, Oct., 1914. Experiment Station grounds, *Clinton*, Oct., 1897. CHRISTIAN CO. Taylorville, *Andrews*, Aug., 1898. COOK CO. Glencoe, *Gates* 1686.2. WABASH CO. Without locality, *Shearer;* Mt. Carmel, *Schneck*, July, 1894.

6. SYNTHERISMA Walt.

Finger Grass. Crab Grass

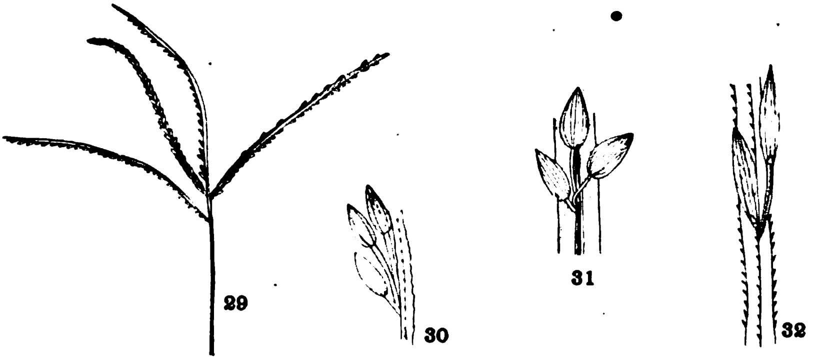
Our species of this genus are annuals. One species, *Syntherisma filiformis*, appears to be a native of Illinois; the other two species are known to have been introduced within the last century. The inflorescence consists of digitate, spike-like racemes, hence the common name, finger grass. The spikelets are arranged in groups of two or three, one subsessile or on a very short pedicel, the others on pedicels as long as the spikelets or longer. The leaves are usually thin and lax, the ligules short and membranous.

Rachis with the lateral angles winged; culms spreading, often rooting at the lower nodes.

Pedicels sharply 3-angled; first glume present; sheaths densely pubescent. ***S. sanguinalis***

Pedicels rounded; first glume wanting; sheaths smooth. ***S. ischaemum***

Rachis with wingless angles; culms erect, never spreading and rooting at the lower nodes. ***S. filiformis***



Figs. 29–32.—29, *S. ischaemum,* inflorescence; 30, *S. filiformis,* group of spikelets; 31, *S. ischaemum,* group of spikelets; 32, *S. sanguinalis,* group of spikelets

Syntherisma filiformis (L.) Nash

Slender Finger Grass (Fig. 30)

Digitaria filiformis, Engelmann '44, 103. *Panicum filiforme,* Lapham '57, 548, 593; Patterson '76, 52; Flagg '78, 284; Brendel '87, 88. *Syntherisma filiformis,* Gleason '07, 181. *Digitaria filiformis,* Gleason '10, 147.

Culms 6 to 28 inches long, erect; leaves short, grouped at the base of the plant; at least the lower sheaths pubescent; racemes 2 to 5, generally erect; spikelets pubescent, 1.7 to 1.8 mm. long, mostly in threes.

This grass is found in dry, sandy soil, usually along roadsides and in waste places. It is not abundant in Illinois.

ILLINOIS SPECIMENS: Without locality, *M. S. Bebb* in 1860. CHRISTIAN CO. Taylorville, *Andrews,* July, 1898. MENARD CO. Without locality, *Hall;* Athens, *Hall,* Sept., 1866. ST. CLAIR CO. Without locality, *Brendel* in 1850; Mascoutah, *Welsch.* WABASH CO. Without locality, *Shearer.*

Syntherisma ischaemum (Schreb.) Nash

Small Crab Grass. Smooth Crab Grass (Figs. 29 and 31)

Panicum glabrum, Lapham '57, 548, 593; Babcock '73, 97; Patterson '76, 52; Flagg '78, 284; Higley and Raddin '91, 139; Huett '97, 128. *Syntherisma linearis,* Britton '07, 77. *Digitaria humifusa,* Gray's Manual, 7th ed., p. 95.

Culms 6 to 24 inches long, spreading over the ground, often rooting at the lower nodes and forming large mats; sheaths and blades smooth and glabrous; racemes 2 to 5, usually 3; spikelets glandular-pubescent between the nerves, 2 to 2.2 mm. long, usually in threes, on rounded pedicels; first glume wanting.

A grass of the same habit as *Syntherisma sanguinalis* and probably often confused with it. It is found as a weed in gardens and cultivated places but is not so common as the above-mentioned species.

ILLINOIS SPECIMENS: Without locality, *Vasey.* CHAMPAIGN CO. Urbana, *Clinton,* Aug., 1899; Urbana, *Seymour,* Sept., 1888. FULTON CO. Without locality, *Pepoon;* Canton, *Wolf.* JO DAVIESS CO. Without locality, *Pepoon.* PEORIA CO. Peoria, *Brendel.* STARK CO. Wady Petra, *V. H. Chase* 131. WILL CO. Mokena, *A. Chase* 2014.

Syntherisma sanguinalis (L.) Dulac

Common Crab Grass. Large Crab Grass (Fig. 32.)

Panicum sanguinale, Lapham '57, 548, 593; Babcock '73, 97; Patterson '76, 52; Flagg '78, 284; Huett '91, 128. *Digitaria sanguinalis,* Gates '12, 354.

Culms 1 to 3 feet long, much branched, spreading, rooting at the lower nodes and forming large mats; sheaths densely hairy; blades more or less pubescent on both surfaces; nodes frequently bearded with reflexed hairs; racemes 3 to 12; spikelets appressed pubescent, 2.5 to 3.5 mm. long, usually in pairs on sharply angled pedicels, first glume minute.

This grass is one of our most troublesome weeds in Illinois, being found in lawns, gardens, and among cultivated crops. It is also found along roadsides and in waste places. Being an annual, it should not be allowed to produce seed. When among crops it is generally destroyed by cultivation, altho its habit of rooting at the lower nodes makes eradication somewhat more difficult than in the case of grasses without this habit. It is most serious, however, as a lawn pest. On account of its habit of growth, it is difficult to cut with the lawn mower, and here it produces seed so close to the ground that it entirely escapes the mower. Hence it comes up from seed year after year, and often, especially in newly-made lawns, entirely crowds out the bluegrass.

ILLINOIS SPECIMENS: Without locality, *M. S. Bebb* in 1861; without locality, *Hall.* CHAMPAIGN CO. Urbana, *Seymour,* June, 1880; Seymour, *Tsou,* Oct., 1913; Urbana, *Gibbs,* Sept., 1898; Urbana, *Clinton,* Aug., 1895; Urbana, *Mosher,* Oct., 1913. CHRISTIAN CO. Taylorville, *Andrews,* July 1, 1898. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Warren, *Pepoon* 479. MCHENRY CO. Algonquin, *Nason,* Aug., 1878. PEORIA CO. Peoria, *McDonald,* Aug., 1887; Peoria, *Brendel.* ST. CLAIR CO. Mascoutah, *Welsch.* WABASH CO. Without locality, *Shearer.*

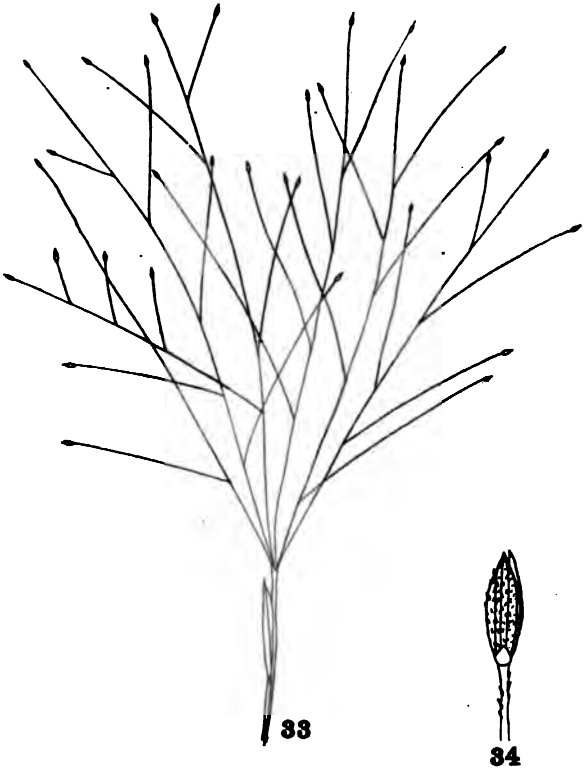
7. **LEPTOLOMA** Chase

This genus is represented in North America by a single species. The plants are perennial with large, open panicles at the ends of brittle culms, the panicles breaking off when the plant is mature and forming tumbleweeds. The spikelets are one-flowered, with a minute first glume. The lemma and palea are thick and leathery. The blades are rather firm with short, membranous ligules.

Leptoloma cognatum (Schult.) Chase
Fall Witch Grass (Figs. 33 and 34)

Panicum autumnale, **Lapham '57, 548, 594; Flagg '78, 284; Brendel '87, 64; Huett '97, 128; McDonald '00, 103.** ***Panicum cognatum,*** **Gleason '07, 181.** ***Leptoloma cognatum,*** **Gleason '10, 147.**

Culms erect, or spreading at base, much branched, 1 to 2.5 feet long, roughened with short, stiff hairs; lower sheaths sometimes slightly pubescent, the upper smooth; blades 1 to 3 inches long, 4 to 6 mm. wide, smooth except for slightly roughened edges; panicle spreading, hairy in the axils; spikelets appressed pubescent, 2.7 to 3 mm. long, single on the ends of long pedicels.



Figs. 33–34.—33, *L. cognatum,* inflorescence; 34, *L. cognatum,* spikelet

This grass is not abundant in Illinois. It occurs mainly in the sand areas thruout the state.

ILLINOIS SPECIMENS: Without locality, *Vasey.* FULTON CO. Without locality, *Pepoon.* HENDERSON CO. Sandy banks of the Mississippi near Oquawka, *Patterson,* Sept., 1873; Oquawka, *Patterson,* Sept., 1881. JO DAVIESS CO.

Without locality, *Pepoon* 182. KANKAKEE CO. Kankakee, *De Selm*, Sept., 1913; Altorf, *Hill*, July, 1873. MACON CO. Decatur, *Clokey*, Sept., 1898. MASON CO. Without locality, *M. S. Bebb* in 1861. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald*, Aug., 1889. ST. CLAIR CO. Mascoutah, *Welsch*.

8. PASPALUM L.

This genus includes a large number of species, most of which are found in warm climates. None of the species are abundant in the state; for the most part they are found in the southern half. The inflorescence consists of spike-like racemes which are racemose along the main axis. The spikelets are flat on one side and strongly convex on the other, many of them almost hemispherical. They are frequently arranged in pairs on the rachis. These grasses are of no economic importance in the state, as they grow mostly in wet or sandy soil and are not common. The leaves are long and narrow, and often pubescent. The amount of pubescence present is quite variable on all parts of the plant.

a. Rachis thin and leaf-like, more than 2 mm. broad.

b. Spikelets pubescent, 1.5 mm. long, elliptical; blades 1 to 6 inches long, 6 to 14 mm. broad. *P. repens*

bb. Spikelets smooth, 2 mm. long; leaf-blades 2 inches or less long, 2 to 6 mm. broad. *P. dissectum*

aa. Rachis never thin and leaf-like, less than 1 mm. broad.

b. Spikelets pubescent, arranged in pairs.

c. Spikelets less than 2 mm. long, usually 1.5 mm., usually glandular spotted; blades densely pilose. *P. setaceum*

cc. Spikelets 2 mm. or more long, not glandular spotted; leaves velvety, the whole plant grayish. *P. bushii*

bb. Spikelets smooth.

c. Blades ciliate on the margin, the surfaces of the blade either smooth or pubescent; spikelets in pairs.

d. Surfaces of blades smooth or with a few very fine hairs.

e. Spikelets about 2 mm. long, always more than 1.7 mm.

f. Spikelets green; culms erect; blades usually smooth; spikelets averaging 2 mm. in length. *P. ciliatifolium*

ff. Spikelets yellowish or straw color; culms always spreading; blades usually with a few fine hairs on the upper surface; spikelets usually more than 2 mm. long. *P. stramineum*

ee. Spikelets 1.5 to 1.7 mm. long; leaves usually ciliate on the midnerve. *P. longepedunculatum*

dd. Surfaces of blades, both upper and under, densely pubescent; plants erect; spikelets 2 to 2.5 mm. long. *P. muhlenbergii*

cc. Blades not ciliate on the margin; spikelets usually arranged singly.

d. Blades conspicuously pubescent.

e. Spikelets about 2 mm. long, arranged in pairs; culms spreading or prostrate. *P. supinum*

ee. Spikelets 2.5 to 2.8 mm. long, arranged singly; sheaths and blades long pilose; culms erect. *P. longipilum*

dd. Blades smooth or slightly pubescent; spikelets arranged singly.

e. Spikelets 3 to 3.2 mm. long; leaf-blades and lower sheaths with a few hairs; blades reaching the base of the panicle or exceeding it. *P. circulare*

ee. Spikelets 2.5 to 2.9 mm. long; plants smooth; panicle much exceeding the blades. *P. lacve*

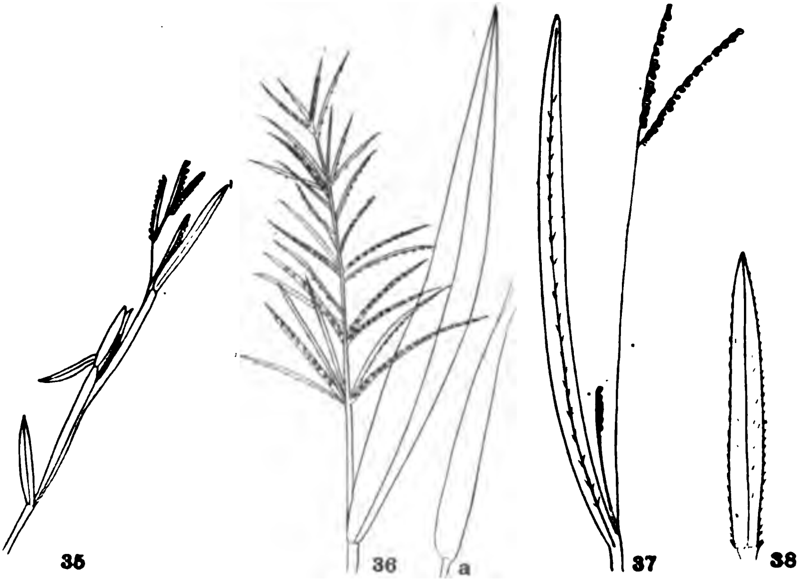
Paspalum bushii Nash

(Fig. 39)

Culms erect, 2.5 to 3.5 feet long, smooth; leaves gray-green; lower sheaths finely pubescent, the upper sheaths ciliate on the margin; blades long, usually 8 to 10 mm. wide, ciliate on the margins, densely velvety on both surfaces, and with a few long hairs intermixed; racemes 2 or 3; spikelets in pairs, 2 to 2.2 mm. long, pale yellowish, oval, densely pubescent.

This species is found in dry soil and is probably rare in Illinois.

CASS CO. Chandlerville, *Seymour*, Aug., 1886. HENDERSON CO. Oquawka, *Patterson*.



Figs. 35–38.—35, *P. dissectum*, inflorescence; 36, *P. repens*, inflorescence, (a) inflated sheath; 37, *P. longepedunculatum*, inflorescence; 38, *P. stramineum*, leaf

Paspalum ciliatifolium Michx.

(Fig. 40)

Culms erect, 16 to 32 inches long, smooth; sheaths smooth; blades long, thin, 6 to 15 mm. wide, smooth and glabrous on both surfaces or occasionally with a few hairs along the midnerve on the under side, long ciliate on the margins; racemes single or in pairs; spikelets in pairs, oval or round, 1.8 to 2.2 mm. long, usually smooth and glabrous, but sometimes with short, appressed hairs.

HENDERSON CO. Oquawka, *Patterson*, Aug., 1874. MARION CO. Without locality, *Brendel*. PEORIA CO. Peoria, *McDonald*, Sept., 1900. WABASH CO. Mt. Carmel, *Waite*, Aug., 1887.

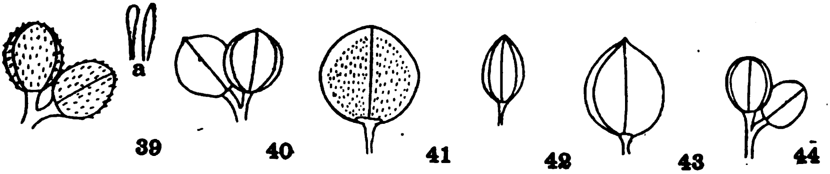
Paspalum circulare Nash

Round-flowered Paspalum (Fig. 41)

Culms erect or slightly reclining, 1 to 2.5 feet long, smooth; sheaths flattened, the lower ones densely pubescent; blades long, narrow, 5 to 8 mm. wide, with long hairs on the upper surface near the base, usually smooth and glabrous on the under surface, but sometimes with a few long hairs; racemes 1 to 4, usually 2 or 3; spikelets arranged singly, smooth, circular in outline, 3 to 3.2 mm. long.

This species is usually found in moist places. It resembles *P. laeve,* from which it may be distinguished by the pubescent sheaths and larger spikelets.

CLINTON CO. Shattuck, *Waite,* Aug., 1887. ST. CLAIR CO. Without locality, *Brendel.* WABASH CO. Mt. Carmel, *Patterson,* Sept., 1877.



Figs. 39–44.—39, *P. bushii,* spikelets, (a) glandular hairs; 40, *P. ciliatifolium,* spikelets; 41, *P. circulare,* spikelet; 42, *P. dissectum,* spikelet; 43, *P. laeve,* spikelet; 44, *P. longepedunculatum,* spikelets

Paspalum dissectum L.

Walter's Paspalum (Figs. 35 and 42)

Paspalum walterianum, Patterson '76, 52; Flagg '78, 284; Brendel '87, 88.

Culms much branched, usually spreading along the ground at the base and often rooting at the lower nodes, 1 to 2 feet long, the flowering culms erect or ascending; sheaths somewhat inflated, smooth; blades always less than 3 inches in length, usually much shorter, smooth; racemes 3 to 7, alternate, about an inch in length, usually partly included in the upper sheath, rachis flattened, green and membranous, 2 to 3 mm. wide; spikelets arranged in two rows, smooth, oval, 2 to 2.2 mm. long.

This species is found in damp or wet places along ditches and streams.

PERRY CO. Du Quoin, *Eggert* in 1893. PULASKI CO. Mound City, *Brendel,* Aug., 1853. ST. CLAIR CO. Without locality, *Brendel* in 1850; without locality, *Brendel,* Aug., 1851; Mascoutah, *Welsch.*

Paspalum laeve Michx.

Field Paspalum. Smooth Paspalum (Fig. 43)

Paspalum laeve, Lapham '57, 548, 592 (Plate 4, Fig. 3); Patterson '76, 52; Flagg '78, 284; Brendel '87, 88.

Culms sometimes erect but oftener spreading, or even lying flat on the ground, 1 to 3 feet long; sheaths smooth and glabrous, sometimes ciliate on the margins, but never pubescent; blades long, but seldom more than 8 inches, 4 to 8 mm. wide, smooth; racemes 2 to 6, commonly 2 or 3, hairy in the axils, not over 3.5 inches long; spikelets arranged singly in two rows, smooth, 2.5 to 2.9 mm. long.

This is one of the commonest species of Paspalum in localities where this genus is found. There are two varieties, *P. laeve australe,* which has blades pilose above and sometimes towards the base beneath, and *P. laeve angustifolium,* which has much longer blades, usually over 8 inches, commonly folded, with a few hairs on the upper surface, and racemes which are usually four inches in length. These varieties are usually found in the same localities as the species, but none have, as yet, been seen from Illinois. This species is usually found in moist fields and meadows.

ILLINOIS SPECIMENS: Without locality, southern Illinois, *Vasey.* HENDERSON CO. Oquawka, *Patterson*, Sept., 1877. MARION CO. Without locality, *M. S. Bebb* in 1860. PEORIA CO. Peoria, *Brendel* in 1853. PERRY CO. Du Quoin, *Seymour*, Aug., 1880. ST. CLAIR CO. Mascoutah, *Welsch.* WABASH CO. Without locality, *Shearer;* Mt. Carmel, *Patterson,* Sept., 1877.

Paspalum longepedunculatum Le Conte

Long-stalked Paspalum (Figs. 37 and 44)

Culms usually spreading or reclining, slender, smooth, 12 to 20 inches long; leaves mostly clustered at the base of the plant; sheaths smooth; blades long-ciliate on the margins, usually smooth on both surfaces, but sometimes pubescent on the upper surface; blades usually not over four inches long, 4 to 6 mm. wide; racemes 1 or 2 on a very long, slender peduncle; spikelets in pairs, smooth, 1.5 to 1.7 mm. long.

This species is found in dry or sandy soil in about the same situations as *P. muhlenbergii.*

PEORIA CO. Peoria, *McDonald,* Sept., 1900. ROCK ISLAND CO. Rock Island, banks of the Mississippi river, *McDonald,* Aug., 1900.

Paspalum longipilum Nash

Long-haired Paspalum (Fig. 45)

Paspalum plenipilum, Gray's Manual, 7th ed., Britton '07.

Culms erect, 1 to 3 feet long, smooth; sheaths flattened, with hairs about equal to the sheath in width, more numerous along the margin and midnerve; blades usually erect, often folded, densely pubescent on the upper surface, the hairs longer near the base, less densely pubescent on the lower surface; racemes 2 to 6, usually 3, on a long peduncle, densely hairy in the axils; spikelets oval, smooth, arranged singly, 2.5 to 2.8 mm. long.

This species somewhat resembles *P. laeve,* but is distinguished by the pubescent sheaths. The hairs on sheaths and blades are much longer than in either variety of *P. laeve.*

RICHLAND CO. Olney, *Ridgway,* in 1914. WABASH CO. Without locality, *Shearer.*

Paspalum muhlenbergii Nash

(Fig. 46)

Culms usually erect, but often spreading or reclining, 16 to 32 inches long, smooth; sheaths usually pubescent; blades long and narrow, 5 to 10 mm. wide, usually wider near the middle, ciliate on the margins, appressed pubescent on both surfaces; racemes 1 or 2; spikelets in pairs, smooth, 2 to 2.5 mm. long.

This species is generally found in sandy soil, along roadsides, in vacant lots, and other uncultivated places.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHRISTIAN CO. Taylorville, *Andrews*. JACKSON CO. Without locality, *French*, July, 1878. MACOUPIN CO. Carlinville, Robertson in 1881. MARION CO. Without locality, *Brendel* in 1860. PEORIA CO. Peoria, *Brendel* in 1859. POPE CO. Herod, *Clinton*, July, 1898. ST. CLAIR CO. Without locality, *Brendel;* Mascoutah, *Welsch*. WABASH CO. Without locality, *Shearer*.

Paspalum repens Berg.

Water Paspalum (Figs. 36 and 47)

Paspalum fluitans, Lapham '57, 548, 592; Patterson '76, 52; Flagg '78, 284; Brendel '87, 88. *Paspalum mucronatum*, Britton '07, 73.

Culms ascending, 6 to 36 inches long, much branched, the branches spreading out at the base; sheaths inflated, very loose, either smooth or slightly pubescent; blades 2 to 8 inches long, 6 to 25 mm. wide, very thin, slightly rough; racemes 10 to 40, the rachis flattened and membranous; spikelets arranged in two rows, slightly pubescent, 1 to 1.5 mm. long.

This species is usually found in water, with the stems floating, the inflated sheaths serving as floats. It is found sometimes in wet, muddy places.

ILLINOIS SPECIMENS: Without locality, southern Illinois, *Vasey;* without locality, southern Illinois, *Forbes*. HENDERSON CO. Oquawka, *Patterson*, Sept., 1877. JERSEY CO. Bottom lands, Grafton, *Seymour*, Oct., 1882. JOHNSON CO. Belknap, *Gleason*, Aug., 1902. PULASKI CO. Mound City, Vasey. ST. CLAIR CO. Without locality, *Brendel*, Aug., 1850; Mascoutah, *Welsch*.

Paspalum setaceum Michx.

(Fig. 48)

Lapham '57, 592; Patterson '76, 52; Flagg '78, 284; Brendel '87, 88; McDonald '00, 103; Gleason '07, 181; Gleason '10, 147.

Culms usually erect, 1 to 2 feet long, smooth and slender; lower sheaths and blades densely pubescent; racemes usually single, occasionally 2, on a long, slender peduncle; spikelets in pairs, almost circular, 1.5 mm. long, usually pubescent and glandular spotted, but sometimes smooth and glabrous.

This species has been confused with *P. muhlenbergii*, which has much larger spikelets. Many of the herbarium specimens of *P. muhlenbergii* examined were labeled *P. setaceum*, so it is quite possible that the citations above refer to both species.

LEE CO. Dixon, *Vasey*. MASON CO. Without locality, *Wolf;* without locality, *Hall;* Devil's Hole, Havana, *Gates* 3439.

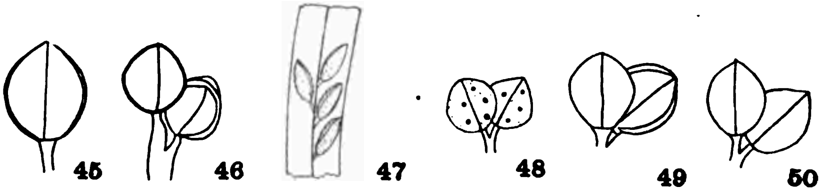
Paspalum stramineum Nash

Straw-colored Paspalum (Figs. 38 and 49)

Culms often spreading or almost flat on the ground, smooth, 8 to 24 inches long; leaves yellowish green or straw color; sheaths smooth and glabrous except on the margin, where there is a fringe of short hairs; blades rather firm, ciliate on the margin, at least 10 mm. wide, some very fine hairs on the upper surface, smooth and glabrous on the under surface; spikelets in pairs, yellow or almost white, usually smooth, almost circular, very thick, 2 to 2.2 mm. long.

This species is found in sandy places and is easily distinguished by the pale color of leaves and spikelets.

CASS CO. Beardstown, *McDonald* in 1900. JO DAVIESS CO. Sandy prairie near Mississippi river, *Pepoon* 399. KANKAKEE CO. Kankakee, *Hill*, Aug., 1872; Altorf, *Hill*, Aug., 1872. WABASH CO. Mt. Carmel, *Waite*, Aug., 1887.



Figs. 45–50.—45, *P. longipilum*, spikelet; 46, *P. muhlenbergii*, spikelets, 47, *P. repens*, spikelets; 48, *P. setaceum*, spikelets; 49, *P. stramineum*, spikelets; 50, *P. supinum*, spikelets

Paspalum supinum Bosc.

(Fig. 50)

Culms spreading or lying flat on the ground, 2 to 3 feet long, smooth; sheaths and blades conspicuously pubescent; blades long, usually 1 foot or more, 5 to 15 mm. wide; spikelets in pairs, smooth, oval, about 2 mm. long.

This species closely resembles *P. bushii* in the "fuzzy" appearance of the leaves, but is distinguished by the glabrous spikelets. In *P. bushii* the culms are erect, but never in *P. supinum.*

MASON CO. Manito, *Wilcox* 56. UNION CO. Anna, *Seymour*, Aug., 1880. WABASH CO. Mt. Carmel, *Patterson* in 1877.

9. **PANICUM** L.

This genus belongs typically to warm climates and includes a very large number of species, of which thirty-six have been found in Illinois. A few of these are weeds, but the majority of them are of no economic importance. Most of the species are perennials, but a few are annuals, and among the annuals are found the species which are common weeds. The inflorescence usually consists of many-flowered panicles. The spikelets have two glumes and a sterile lemma, which are usually strongly nerved, and a very hard, shiny, fertile lemma and palea inclosing the fruit, which are never nerved. This genus was recently revised by Hitchcock and Chase (Contributions from the U. S. Nat. Herb., Vol. 15, 1910). The Illinois species have been arranged in groups following their classification, then arranged alphabetically under the different groups.

- a. Spikelets smooth and glabrous.
  - b. Plants never forming a winter rosette of leaves at the base of the culm, the leaves all similar.
    - c. Plants annual, without creeping rootstocks.
      - d. First glume not over one-fourth the length of the spikelet, and usually broadly rounded at the apex, never sharp-pointed; plants generally smooth thruout. *P. dichotomiflorum*
      - dd. First glume always one-half the length of the spikelet, or more; plants typically very pubescent, the sheaths usually papillose-hirsute; panicles many-flowered, usually large, with fine capillary branches.
        - e. Spikelets 4.5 to 5 mm. long, panicles often drooping. *P. miliaceum*
        - ee. Spikelets always less than 4 mm. long; panicles never drooping, numerous, one-third the entire height of the plant or more.
          - f. Spikelets 2.5 or more long, usually at least 3 mm.; blades sparsely pubescent.
            - g. Panicles as broad as long, leaves usually crowded at the base of the plant. *P. barbipulvinatum*
            - gg. Panicles narrow, usually less than half as broad as long. *P. flexile*
          - ff. Spikelets only rarely exceeding 2.2 mm. long; blades generally densely pubescent.
            - g. Culms slender; the panicles delicate, relatively few-flowered; spikelets less than 2 mm. long, usually in pairs at the ends of the naked panicle branches. *P. philadelphicum*
            - gg. Culms stout; panicles diffuse, many-flowered; spikelets 2 mm. or more long.
              - h. Panicles as broad as long, usually more than half the length of the entire plant, mostly terminal only. *P. capillare*
              - hh. Panicles oval, seldom as broad as long, normally one-third the length of the entire plant, or less, produced from all the nodes. *P. gattingeri*
    - cc. Plants perennial, with or without creeping rootstocks.
      - d. Panicles open, the spikelets long pediceled; culms from long, creeping rootstocks, not flattened. *P. virgatum*
      - dd. Panicles somewhat contracted and resembling those of common redtop, (*Agrostis alba*); culms flattened, sheaths keeled.
        - e. Long, scaly rootstocks present; spikelets 3.4 to 3.8 mm. long. *P. anceps*
        - ee. Rootstocks never present; spikelets 1.8 to 2 mm. long. *P. agrostoides*
  - bb. Plants forming a winter rosette at the base of the culm, these much shorter and broader than the culm leaves.
    - c. Spikelets over 3 mm. long.
      - d. Spikelets pointed or beaked; blades very long and narrow, usually stiff and erect from the base of the plant; panicle narrow and few-flowered. *P. depauperatum*
      - dd. Spikelets blunt; blades short and rather broad, distributed along the culm; panicle nearly as broad as long, but not densely flowered. *P. scribnerianum*

cc. Spikelets less than 3 mm. long.

d. Blades very long and narrow, not over 5 mm. wide, usually all erect from the base of the plant and usually longer than the panicle until it is mature; spikelets 2.2 to 2.7 mm. long; sheaths pilose. *P. linearifolium*

dd. Blades not elongated, not in a tuft at the base of the plant, the panicle always considerably above the leaves; sheaths smooth, or the lowermost sometimes puberulent.

e. Spikelets more than 2 mm. long, pointed; sheaths with pale glandular spots. *P. yadkinense*

ee. Spikelets 2 mm. or less long, not pointed.

f. Nodes bearded.

g. Ligule not present; spikelets 1.5 to 1.6 mm. long. *P. microcarpon*

gg. Ligule present; spikelets 2 mm. long; at least the lower nodes bearded; fruit always covered by the second glume and sterile lemma. *P. barbulatum*

ff. Nodes not bearded; spikelets 2 mm. long; the fruit exposed at tip, never quite covered by the second glume and sterile lemma. *P. dichotomum*

aa. Spikelets more or less pubescent.

b. Blades broad, usually more than 1.5 cm. wide, cordate at base; culms stout, usually two feet or more high; spikelets over 2.5 mm. long.

c. Sheaths, at least the lower ones, hispid, the hairs arising from prominent papillae; spikelets 2.7 to 3 mm. long. *P. clandestinum*

cc. Sheaths smooth, or with a few soft hairs.

d. Nodes smooth; spikelets less than 4 mm. long. *P. latifolium*

dd. Nodes bearded; spikelets 4 to 4.5 mm. long. *P. boscii*

bb. Blades narrow, at least not over 1.5 cm. wide, usually not cordate at base; culms never as stout, rarely as tall, as in the preceding species.

c. Spikelets 2 mm. or more long.

d. Blades much elongated, the length usually more than fifteen times the breadth, less than 5 mm. wide, the leaves growing mostly erect from the base and forming tufts.

e. Spikelets about 3.5 mm. long, pointed or beaked. *P. depauperatum*

ee. Spikelets 3 mm. long or less, not pointed or beaked.

f. Culms in small tufts; spikelets 2.7 to 3.2 mm. long, almost as broad as long. *P. perlongum*

ff. Culms in large tufts; spikelets 2.2 to 2.7 mm. long, distinctly longer than broad. *P. linearifolium*

dd. Blades usually not elongated, generally over 5 mm. wide; leaves not all clustered at the base of the plant, but distributed along the culm.

e. Spikelets more than 3 mm. long; culms stout, erect, with stiff blades, and usually pubescent sheaths.

f. Plants densely pubescent thruout, the hairs arising from small papillae, those on the sheaths spreading; panicle narrow, always longer than wide. *P. leibergii*

ff. Plants not densely pubescent thruout, usually with few hairs on the blades, the upper surface normally smooth; panicle about as wide as long.

g. Spikelets distinctly longer than broad, somewhat pointed, usually pubescent; plants olivaceous, pubescence appressed. *P. oligosanthes*

gg. Spikelets nearly as broad as long, blunt, usually nearly smooth; plants always bright green or yellowish green, pubescence not appressed. *P. scribnerianum*

ee. Spikelets less than 3 mm. long.

f. Leaves densely pubescent on both surfaces, the entire plant pubescent; spikelets 2.2 to 2.4 mm. long.

g. Hairs on the culms and sheaths spreading horizontally. *P. villosissimum*

gg. Hairs on the culms and sheaths not spreading horizontally, but appressed or ascending. *P. pseudopubescens*

ff. Leaves not densely pubescent on both surfaces, the entire plant not noticeably pubescent.

g. Blades ciliate, otherwise glabrous, or with a few fine hairs; spikelets 2 mm. long; sheaths retrorsely pilose; blades very soft. *P. xalapense*

gg. Blades broad, sometimes ciliate around the cordate base; spikelets 2.5 to 3 mm. long; sheaths smooth; blades firm. *P. commutatum*

cc. Spikelets less than 2 mm. long.

d. Culms and sheaths densely and usually conspicuously pubescent; ligules densely hairy, 2 to 5 mm. long.

e. Spikelets more than 1.5 mm. long.

f. Culms conspicuously pubescent with long, soft, horizontally spreading hairs; blades pubescent, the hairs nearly as long as the width of the blade; spikelets 1.8 to 1.9 mm. long. *P. praecocius*

ff. Culms and blades pubescent, with short, appressed hairs.

g. Upper surface of blades smooth, or with only a few hairs near base; blades with a thin, white margin; spikelets 1.6 to 1.7 mm. long. *P. tennesseense*

gg. Upper surface of blades pubescent; blades never with a thin, white margin; spikelets 1.6 to 1.8 mm. long. *P. huachucae*

ee. Spikelets 1.5 mm. or less long.

f. Summit of the culm with long hairs, panicle branches tangled. *P. implicatum*

ff. Summit of the culm without hairs; panicle branches not tangled. *P. meridionale*

g. Culms and sheaths not conspicuously pubescent, either smooth or with short, appressed hairs; ligules (except in *P. lindheimeri*) generally very short, not over 1.5 mm. long.

h. Spikelets not spherical, longer than broad; ligules always visible; blades narrow.

i. Sheaths ciliate, otherwise glabrous or the lower sparsely pilose, about half the length of the internode; ligule densely hairy, 3 to 5 mm. long. *P. lindheimeri*

ii. Sheaths appressed pubescent, very little shorter than the internodes; ligules about 1 mm. long. *P. tsugetorum*

hh. Spikelets spherical or nearly so; ligules obsolete or nearly so; blades broad.

i. Panicle nearly as broad as long; blades not distinctly nerved. *P. sphaerocarpon*

ii. Panicle about two-thirds as broad as long; blades distinctly nerved. *P. polyanthes*

DICHOTOMIFLORA

Only one species of this group is found in Illinois. These are annual plants, typically smooth thruout, with large, spreading panicles 4 to 16 inches long. The leaves are long and narrow, the ligules 1 to 3 mm. long, membranous, edged with a fringe of long hairs. The first glume is very short, one-fourth or less the length of the spikelet.

Panicum dichotomiflorum Michx.

Sprouting Crab Grass (Fig. 51)

Panicum proliferum, Lapham '57, 548, 549; Patterson '76, 52; Flagg '78, 284; Brendel '87, 64. *Panicum dichotomiflorum*, Hitchcock and Chase '10, 51.

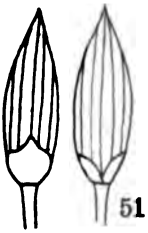


Fig. 51.—*P. dichotomiflorum*, spikelet

Entire plant usually smooth and glabrous; culms 1 to 4 feet long, somewhat flattened, usually spreading at the base, but sometimes erect, geniculate at the nodes, the nodes often considerably swollen; sheaths loose, very often purplish; blades 4 to 20 inches long, 3 to 20 mm. broad; spikelets smooth, 2 to 3 mm. long, usually 2.5 mm.

This species is usually found in moist ground and along ditches and streams, and generally produces a very rank growth. It also occurs as a weed in waste places and cultivated soil, often forming a rank growth after crops have been removed. In such situations it must be regarded as a weed, but it is not usually very troublesome as it is an annual and can be easily controlled if thoro cultivation is given the soil and no seed is allowed to form.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Champaign, *Gibbs*, Oct., 1886; Champaign, *Mosher*, Oct., 1914; Urbana, *Gibbs*, Sept., 1898; Urbana, *Seymour*, Aug., 1880; Urbana, *Mosher*, Sept., 1914. CHRISTIAN CO. Taylorville, *Andrews*, Aug., 1898. COOK CO. Chicago, *Umbach* in 1896; Chicago, *Moffatt* 374. FULTON CO. Without locality, *Pepoon* 485; Canton, *Wolf*. HANCOCK CO. Without locality, *Mead* in 1842. JACKSON CO. Makanda, *Seymour*, Aug., 1880. JO DAVIESS CO. Warren, *Pepoon* 485. KANKAKEE CO. Kankakee, *De Selm*, Sept., 1913. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald* 71. PIATT CO. White Heath, *Mosher*, Oct., 1914. ST. CLAIR CO. Without locality, *Eggert* 110; Mascoutah, *Welsch*. WABASH CO. Without locality, *Schneck* in 1904; without locality, *Shearer;* Mt. Carmel, *Schneck* in 1888.

CAPILLARIA

The plants in this group are all annuals. They are very pubescent, usually on both culms and leaves, but at least on the leaves. The hairs arise from small, rounded papillae. The ligules are about 3 mm. long and are fringed with hairs. The panicles are of the type shown in Fig. 33, usually large, from 4 to 18 inches long, and at maturity they often break away from the plant and become tumble-weeds. The spikelets are smooth and the first glume is always at least one-third the length of the spikelet. Six species of this group are found in Illinois.

Panicum barbipulvinatum Nash

(Fig. 52)

Hitchcock and Chase '10, 63.

Culms erect, 6 inches to 3 feet long, pubescent below the nodes; sheaths very pubescent; blades sparsely pubescent on both surfaces, 1.5 to 6 inches long, 3 to 12 mm. wide; panicles broad and spreading, often almost half the length of the plant, few-flowered; spikelets smooth, 3 to 3.3 mm. long, usually about 3 mm.

This species very closely resembles *P. capillare*; at first sight the two might be considered identical. *P. barbipulvinatum,* however, has a much thinner and more spreading panicle, its blades are not so hairy and its spikelets are larger.

HENDERSON CO. Vicinity of Oquawka, *Patterson.*

Panicum capillare L.

Witch Grass. Tumble-weed. Old Witch Grass. Tickle Grass

(Fig. 53)

Michaux '03, 47; Lapham '57, 548, 594; Babcock '73, 97; Patterson '76, 52; Flagg '78, 284; Brendel '87, 64; Higley and Raddin '91, 139; Huett '97, 128; Hitchcock and Chase '10, 60; Gates '12, 354; Sherff '13, 594.

Culms usually erect, 8 inches to 4 feet long, pubescent, especially at the nodes; sheaths densely pubescent, the hairs nearly as long as the sheath is wide; blades 4 to 10 inches long, 5 to 15 mm. wide, the midrib prominent, both surfaces thickly covered with short, appressed pubescence; panicle many-flowered, included in the sheath till maturity, then very large and spreading, sometimes half the length of the plant, nearly circular in outline, finally breaking away from the plant and acting as a tumble-weed; spikelets 2 to 2.5 mm. long.

This is a very common species in Illinois, by far the most common of this group. It is a weed in cornfields and among other cultivated crops. It is also found along ditches and in other moist places. It is easily eradicated by cultivation if care is taken to destroy the plants before the seed forms.

CHAMPAIGN CO. Urbana, *Gibbs,* Sept., 1898; Urbana, *Mosher,* Oct., 1913; Urbana, *Clinton,* Aug., 1895; Seymour, *Tsou,* Oct., 1913. COOK CO. Chicago, *Robert Bebb* 2917; Chicago, *Babcock,* Sept., 1874. DU PAGE CO. Naperville, *Umbach* in 1898. FORD CO. Roberts, *Wilcox* 109. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon* 478. KANKAKEE CO. Kankakee, *De Selm,* Sept., 1913. LAKE CO. Lake Forest, *Jensen,* Aug., 1895. MCHENRY CO. Algonquin, *Nason,* Aug., 1879. PEORIA CO. Peoria, *McDonald,* Sept., 1904. PIATT CO. White Heath, *Mosher,* Oct., 1914. ST. CLAIR CO. Cahokia, *Eggert,* Sept., 1875; Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase* in 1897. WABASH CO. Without locality, *Shearer,* Sept., 1899; Mt. Carmel, *Schneck,* Sept., 1876. WILL CO. Mokena, *A. Chase* 2008.

Panicum flexile (Gattinger) Scribn.

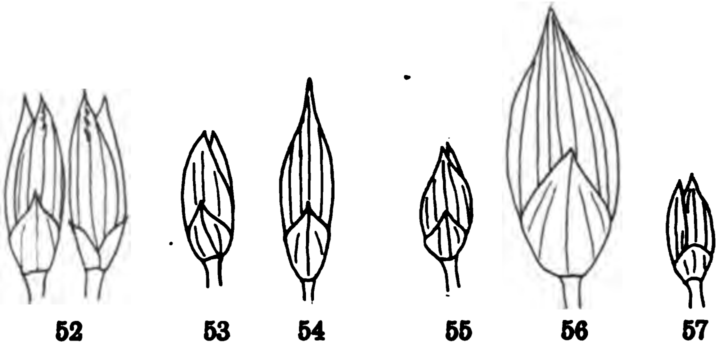
(Fig. 54)

Hitchcock and Chase '10, 55.

Culms erect, 8 to 20 inches long, almost smooth except at the nodes; sheaths pubescent, the hairs about half as long as the width of the sheath, but not very conspicuous; blades sparsely pubescent or smooth, 4 to 12 inches long, 2 to 6 mm. wide; panicles narrow, few-flowered, seldom half the length of the plant; spikelets smooth, 3 to 3.5 mm. long.

This is not a common species in Illinois. It is found in sandy soil, usually where it is moist. It is readily distinguished from *P. capillare* by its slender habit of growth, less dense pubescence on the sheaths, smaller, narrower panicles, narrower leaves, and larger, more pointed spikelets. Its habit of growth is more like that of *P. philadelphicum*, from which it is distinguished by its narrower panicle, and longer, pointed spikelets.

COOK CO. Chicago, *A. Chase* 1474, 1479, 1729, 2006; Chicago, *Hill* in 1901; Irondale, Chicago, *A. Chase* 1473; Grand Crossing, *Robert Bebb* 2928; Grand Crossing, *McDonald*, Sept., 1893. LAKE CO. Beach, *Umbach* 2543. ST. CLAIR CO. Without locality, *Eggert* 241. WABASH CO. Without locality, *Shearer*, Oct., 1915; Mt. Carmel, *Schneck*, Sept., 1879.



Figs. 52–57.—Spikelets: 52, *P. barbipulvinatum;* 53, *P. capillare;* 54, *P. flexile;* 55, *P. gattingeri;* 56, *P. miliaceum;* 57, *P. philadelphicum*

Panicum gattingeri Nash
(Fig. 55)

Hitchcock and Chase '10, 57.

Culms 8 inches to 3 feet long, erect at first, but soon spreading and rooting at the lower nodes; culms, nodes, and sheaths densely pubescent, the hairs almost as long as the width of the culm; blades 4 to 8 inches long, 6 to 10 mm. wide, sparsely pubescent or smooth; panicles numerous, oval in outline, never as much as half the length of the plant; spikelets usually 2 mm. long.

This species is very closely related to *P. capillare* but differs in the spreading habit, the more oval outline of the panicle and the shorter, broader spikelets. It is usually a weed and is found in the same situations as *P. capillare.* It may easily be eradicated by cultivation, which prevents the formation of seed.

CHAMPAIGN CO. Urbana, *Seymour*, Oct., 1880. FULTON CO. Canton, *Wolf* in 1882. PEORIA CO. Peoria, *Brendel.* STARK CO. Wady Petra, *V. H. Chase*, Sept., 1900; 124 in 1897. VERMILION CO. Catlin, *Lansing*, Sept., 1912. WABASH CO. Without locality, *Shearer*, Aug., 1915.

Panicum miliaceum L.

Broom-corn Millet. Hog Millet (Fig. 56)

Hitchcock and Chase '10, 69.

Culms stout, usually erect, 8 inches to 3 feet high, pubescent below the nodes, which are densely, softly pubescent; sheaths loose, densely pubescent, the hairs not more than half the width of the sheath; blades 4 to 12 inches long and 8 to 20 mm. broad, sparsely long pubescent on both surfaces, sometimes almost smooth; panicles relatively small, rather compact, many-flowered, and usually drooping; spikelets 4.5 to 5 mm. long.

This plant frequently escapes from cultivation and is found in waste places.

COOK CO. Chicago, *A. Chase* 1633; Woodlawn, Chicago, *Millspaugh* 389. LAKE CO. Beach Area, *Gates*. VERMILION CO. Hastings, *S. Gray* in 1905.

Panicum philadelphicum Bernh.

(Fig. 57)

Culms erect and slender, 6 to 20 inches long, usually pubescent but sometimes smooth and glabrous; sheaths densely pubescent, the hairs as long as the width of the sheath and usually perpendicular to it; blades short and narrow, 1 to 4 inches long and 2 to 6 mm. wide, sparsely pubescent; panicles oval in outline, few-flowered, the spikelets mostly in twos, 1.7 to 2 mm. long.

This plant is usually yellowish green and is much smaller and more slender than *P. capillare*. The panicles are very much smaller, never more than one-third the length of the plant, and the spikelets are usually smaller. This species is found in rather dry soil, by roadsides and in waste places. It is rare in Illinois.

ILLINOIS SPECIMENS: Without locality, *Vasey*.

VIRGATA

This group includes plants which are perennial by stout, creeping rootstocks. They are not densely pubescent plants like the Capillaria, the only species in Illinois being practically smooth thruout. The ligules are 2 to 4 mm. long, membranous, and fringed with hairs. The spikelets are large and contain a staminate flower in addition to the perfect one. The first glume is always more than half the length of the spikelet, and the second glume is longer than the sterile lemma.

Panicum virgatum L.

Switch Grass (Fig. 58)

Michaux '03, 48; Engelmann '44, 103; Lapham '57, 548, 594; Babcock '73, 97; Flagg '78, 284; Brendel '87, 64; Higley and Raddin '91, 139; Huett '97, 128; Gleason '07, 181; Gleason '10, 147; Hitchcock and Chase '10, 87; Gates '12, 354.

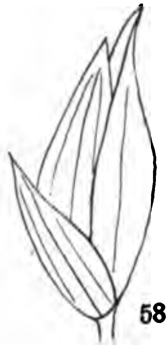


Fig. 58.—*P. virgatum,* spikelet

Culms erect, 3 to 6 feet tall, smooth; sheaths usually smooth, sometimes ciliate on the margin or with a few hairs at the throat; blades 4 inches to 2 feet long, 4 to 15 mm. wide, usually smooth except for the rough edges; panicles large and spreading; spikelets 3.5 to 5 mm. long.

This is a species belonging to the prairie. It is usually found in moist places, where it grows in large bunches. When young, it furnishes some grazing for stock, but when the plant is old the stems are very hard.

ILLINOIS SPECIMENS: Without locality, *Hall* in 1870. COOK CO. Chicago, *A. Chase* 1178, 1636; Chicago, *Babcock,* July, 1874. CHAMPAIGN CO. Without locality, *Percival,* Oct., 1876; Champaign, *Clinton,* Sept., 1897; Champaign, *Seymour,* July, 1880; Savoy, *Gibbs,* Sept., 1898. FULTON CO. Without locality, *Pepoon.* IROQUOIS CO. Thawville, *Wilcox* 100. JO DAVIESS CO. Without locality, *Pepoon* 411. LAKE CO. Waukegan, *Gleason* and *Shobe* 326; Winthrop Harbor, *Gates.* LEE CO. Dixon, *Seymour,* Sept., 1882. MACON CO. Decatur, *Clokey* in 1898. MENARD CO. Athens, *Hall* in 1870. OGLE CO. Without locality, *M. S. Bebb* in 1858; Oregon, *Waite* in 1885. PEORIA CO. Princeville, *V. H. Chase* 818; Peoria, *Brendel;* Peoria, *McDonald,* Aug., 1903. ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase* in 1897. WABASH CO. Without locality, *Shearer;* Old Palmyra, *Schneck,* Sept., 1897; Mt. Carmel, *Schneck,* Oct., 1876. WILL CO. Joliet, *Skeels* 470.

AGROSTOIDEA

These plants are perennials, growing in bunches, some species with scaly rootstocks. The sheaths are often keeled. The ligule is never over a millimeter long, membranous, and sometimes fringed with hairs. The panicles in our species are many-flowered, the spikelets short-pediceled, mostly crowded on the ascending branches. The spikelets are smooth and have a keeled first glume.

Panicum agrostoides Spreng.

Munro Grass (Fig. 60)

Lapham '57, 548, 594; Patterson '76, 52; Flagg '78, 284; Huett '97, 128; Hitchcock and Chase '10, 100.

Culms erect, smooth, 1.5 to 3 feet long, many short leaves clustered at the base of the plant with some very long ones on the culm; sheaths keeled, usually smooth; blades folded at the base, flat above, 8 to 20 inches long, 5 to 10 mm. wide, slightly rough on both surfaces but not pubescent; panicles narrowly oval in outline, much the size and shape of common redtop, *Agrostis alba;* spikelets 1.8 to 2 mm. long.

This species is usually found in damp places, often forming a dense stand over considerable areas that are low and somewhat boggy.

It also grows along the banks of streams and ponds. It furnishes very good fodder if present in sufficient quantities.

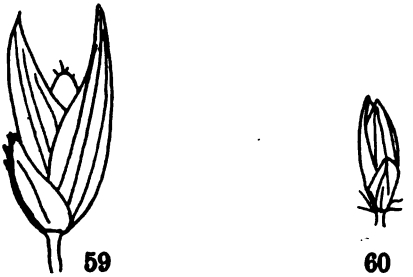
ILLINOIS SPECIMENS: Without locality, Southern Illinois, *Vasey* in 1860. CLINTON CO. Shattuck, *Waite*. HANCOCK CO. Augusta, *Mead*. JACKSON CO. Makanda, *Seymour*, Aug., 1880. KANKAKEE CO. Kankakee, *De Selm*, Aug., 1913. MADISON CO. Madison, *Eggert* 227. PEORIA CO. Peoria, *Brendel* in 1859. PULASKI CO. Mound City, *Vasey*. ST. CLAIR CO. Without locality, *Brendel* in 1850; Mascoutah, *Welsch*. WABASH CO. Without locality, *Shearer*, Sept., 1898.

Panicum anceps Michx.

(Fig. 59)

Brendel '59, 585; Vasey '61, 671; Patterson '76, 52; Flagg '78, 284; Brendel '87, 64; Hitchcock and Chase '10, 107.

Culms erect from stout, scaly rootstocks, smooth, 1.5 to 3 feet long; sheaths finely pubescent or smooth and glabrous; blades often folded together at base, usually slightly rough and glabrous, sometimes a few hairs near the base, 8 to 20 inches long, 4 to 10 mm. wide; panicles stiffly erect, the long slender branches not close together, bearing short, appressed branchlets, mostly along the lower side; spikelets 3 to 3.8 mm. long, usually about 3.5.



Figs. 59–60.—Spikelets: 59, *P. anceps;* 60, *P. agrostoides*

This species is found in moist, sandy soil, often in open woods. It is of no economic importance.

ILLINOIS SPECIMENS: Without locality, *Vasey*. HENDERSON CO. Without locality, *Patterson*. PEORIA CO. Peoria, *Brendel*. POPE CO. Herod, *Clinton*, July, 1898. PULASKI CO. Mound City, *Vasey*. ST. CLAIR CO. Mascoutah, *Welsch*. UNION CO. Anna, *Seymour*, Aug., 1880. WABASH CO. Mt. Carmel, *Waite* in 1887; Paton Station, *Schneck*, Aug., 1881.

Subgenus **DICHANTHELIUM** Hitchcock and Chase

The remaining groups of Panicum are included in this subgenus. In these plants there is a more or less well-marked winter rosette of leaves at the base of the plant, which are broader and shorter than the other leaves (Fig. 67). This rosette is formed in midsummer or fall, and lives over until spring. In the spring simple culms (Fig. 73) are produced, bearing terminal panicles with numerous spikelets, which seldom produce seed (Fig. 67b). After these panicles are mature, the culms branch and the winter rosette is formed. This changes the appearance of the plant completely in most cases (Fig. 67), and some of these autumnal forms have been described as new species. A second lot of panicles, often hidden by the sheaths, are produced on the branches, the spikelets on these producing seed.

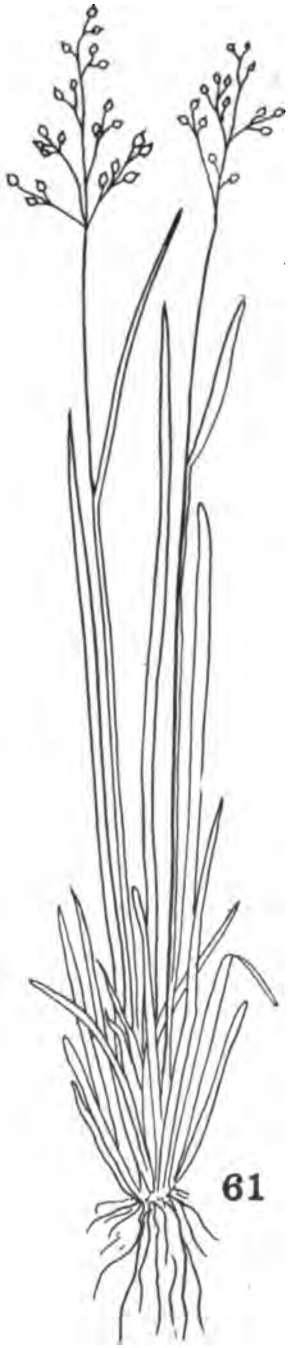


Fig. 61.—*P. depauperatum*

DEPAUPERATA

This group includes plants with simple culms, 4 to 16 inches tall with long, narrow leaves clustered at the base. The ligule is a ring of very short hairs. The panicles are small, very narrow, and in summer are borne well above the leaves. In autumn the panicles are smaller and more or less hidden by the leaves. The species are extremely variable both as to size of spikelet and amount of hairs present.

Panicum depauperatum Muhl.

(Figs. 61 and 64)

Lapham '57, 548, 596; Babcock '73, 250; Patterson '76, 52; Flagg '78, 284; Brendel '87, 64; Higley and Raddin '91, 139; Huett '97, 128; Hitchcock and Chase '10, 151.

Culms slender and stiff, variable as to amount of pubescence present, sometimes smooth and glabrous; sheaths usually finely papillose-pubescent; blades 3 to 9 inches long, 2 to 5 mm. wide, the smaller leaves at the base of the plant; panicles narrow, few-flowered; spikelets beaked. the second glume and sterile lemma extending beyond the fruit, 3 to 4 mm. long, usually about 3.5 mm., sometimes with a few short hairs.

There is little difference between the plant in spring and in autumn. It grows in poor soil, generally in open woods. *Panicum depauperatum* as mentioned by the earlier authors probably included *P. perlongum,* as that species has only recently been segregated from *P. depauperatum.*

ILLINOIS SPECIMENS: Lansing, *A. Chase* 867. JACKSON CO. Makanda, *Gleason,* June, 1903.

Panicum perlongum Nash

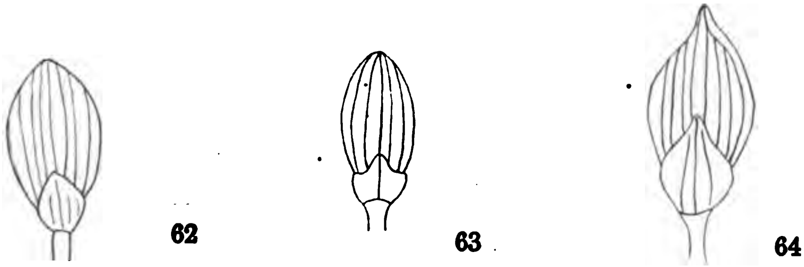
(Fig. 62)

Gleason '10, 148; Hitchcock and Chase '10, 153.

Culms as in the preceding species; sheaths usually densely pubescent, very seldom smooth; blades 2 to 10 inches long, 2 to 4 mm. wide; panicles very small, but appearing densely flowered; spikelets blunt, or if appearing beaked, the points of the second glume and sterile lemma not extending beyond the fruit, 2.7 to 3.3 mm. long, often pubescent.

This species closely resembles *P. depauperatum,* but the spikelets do not have a beak prolonged beyond the fruit, and the leaves are longer and narrower. *P. depauperatum* has very few panicles in the autumn, while *P. perlongum* has a great many. It is a prairie species and grows in dry soil.

ILLINOIS SPECIMENS: Without locality, *Babcock;* without locality, *Wolf.* CHAMPAIGN CO. Urbana, *Seymour,* May, 1880. HENDERSON CO. Oquawka, *Patterson.* JO DAVIESS CO. Hanover, *Gleason* and *Gates* 2530. LAKE CO. Beach, *Gates* 2454; Waukegan, *Gates* 2472. PEORIA CO. Peoria, *McDonald.* STARK CO. Wady Petra, *V. H. Chase* 460, 1456, 1511. WILL CO. Joliet, *Hill,* June, 1907; Joliet, *Skeels,* June, 1904.



Figs. 62–64.—Spikelets: 62, *P. perlongum;* 63, *P. linearifolium;* 64, *P. depauperatum*

Panicum linearifolium Scribn.

(Fig. 63)

Hitchcock and Chase '10, 155.

Culms 8 to 18 inches long, very slender, seldom pubescent; sheaths usually densely pubescent; blades 4 to 15 inches long, often longer than the panicles, 2 to 4 mm. wide; panicles larger than in the two preceding species; spikelets 2.2 to 2.7 mm. long, often with a few soft hairs.

This species is best distinguished by its smaller, narrower spikelets, but the leaves are typically much longer and narrower and not so stiff as in the preceding species. It grows in dry woods.

COOK CO. Glencoe, *Gates,* June, 1907. DU PAGE CO. Wheaton, *Moffatt,* July, 1893. JACKSON CO. Makanda, *Gleason,* June, 1903. ST. CLAIR CO. Mascoutah, *Welsch.* UNION CO. Cobden, *Waite,* June, 1885.

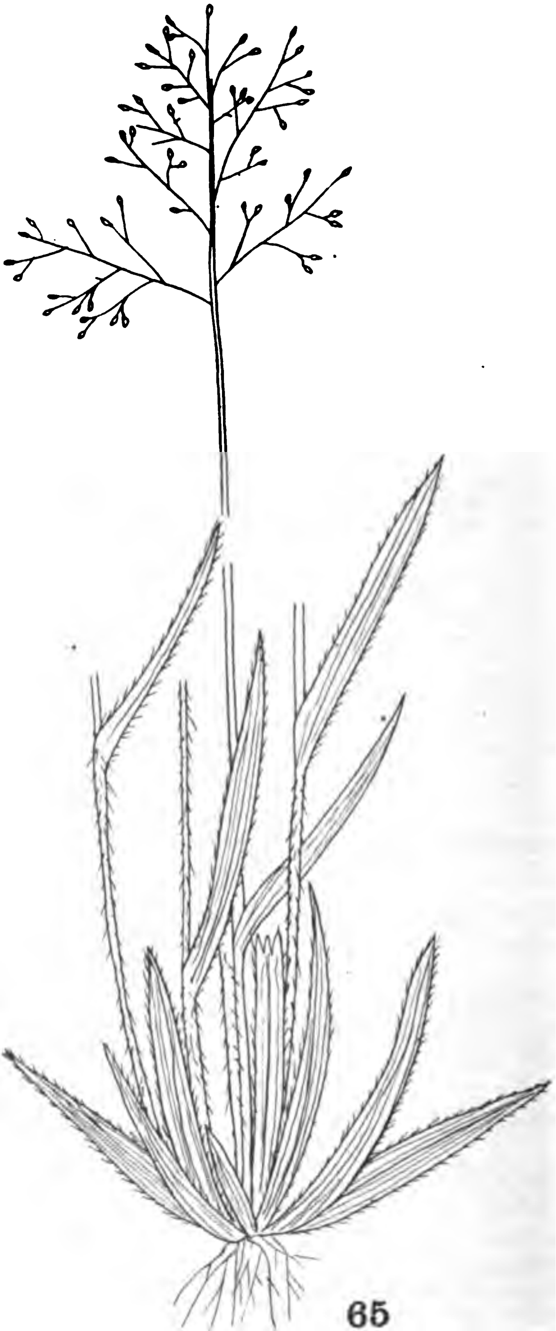


Fig. 65.—*P. xalapense*

LAXIFLORA

The species belonging to this group are characterized by their soft, pale green foliage. The blades in the Illinois species are edged with rather long hairs or cilia and are usually pubescent on both surfaces.

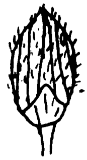
The leaves in summer are always clustered at the base of the plant and are shorter here than on the culm. This cluster of leaves persists in the autumn, but does not form a true rosette such as is found in the next group, Dichotoma. The ligules are very short and inconspicuous. The panicles in summer are borne far above the leaves; in autumn they are smaller and often hidden by them. The spikelets are small, always less than 2.5 mm. in length.

Panicum xalapense H. B. K.

(Figs. 65 and 66)

Hitchcock and Chase '10, 160.

Plants in spring and early summer with smooth, slender culms 8 to 24 inches long; sheaths densely, retrorsely pubescent with long, soft hairs arising from small papillae; blades 4 to 8 inches long, 7 to 12 mm. broad, sparsely pubescent on both surfaces, the edges ciliate, with hairs usually as long as those on the sheaths; panicles few-flowered; spikelets pubescent, about 2 mm. long, sometimes slightly shorter. Plants in autumn more branched at the base, forming denser tufts than in the spring.



66

Fig. 66.—*P. xalapense*, spikelet

This species is most abundant in the southern states. It has been collected only a few times in Illinois.

JACKSON CO. Without locality, *French* in 1905. ST. CLAIR CO. Mascoutah, *Welsch*. UNION CO. Anna, *Seymour*, Aug., 1880.

DICHOTOMA

The plants belonging to this group are strikingly different in spring or early summer, and in autumn. The spring or vernal form has several simple culms in a tuft. The panicles are few-flowered, not very large, and their spikelets rarely perfect seed. In the autumn a small, flat rosette is formed at the base, and the culms branch freely, often resembling miniature trees. These culms often become too heavy to stand erect and are found bent over or lying prostrate on the ground. The dead leaves of the winter rosette are always found at the base of the culms of the vernal form, if care is taken in collecting the plants. The panicles borne in autumn are very much smaller than those of the vernal form, and are usually included in the leaf sheaths, often scarcely visible. Their spikelets always produce seed. The leaves and culms in this group are never conspicuously pubescent, and the ligules are very short, less than 1 mm. in length, and fringed. The spikelets are never over 2.5 mm. in length.

Panicum barbulatum Michx.

(Fig. 68)

Vernal culms 1 to 2.5 feet tall; the lower nodes bearded; sheaths shorter than the internodes, but usually more than half as long, sometimes with a few soft hairs; blades 2.5 to 4 inches long, 6 to 10 mm. wide; panicles borne well above the leaves; spikelets 2 mm. long, smooth, the second glume always covering the ripe fruit. Autumnal culms branched rather more than in *P. dichotomum* and usually reclining, being too top-heavy to stand erect.

This species is found in sterile soil, usually in the woods. In its vernal phase it closely resembles *P. dichotomum,* but it always has bearded nodes.

JACKSON CO. Makanda, *Seymour,* Aug., 1880. PEORIA CO. Peoria, *Brendel.* WABASH CO. Belmont, *Schneck,* Oct., 1900.

Panicum dichotomum L.

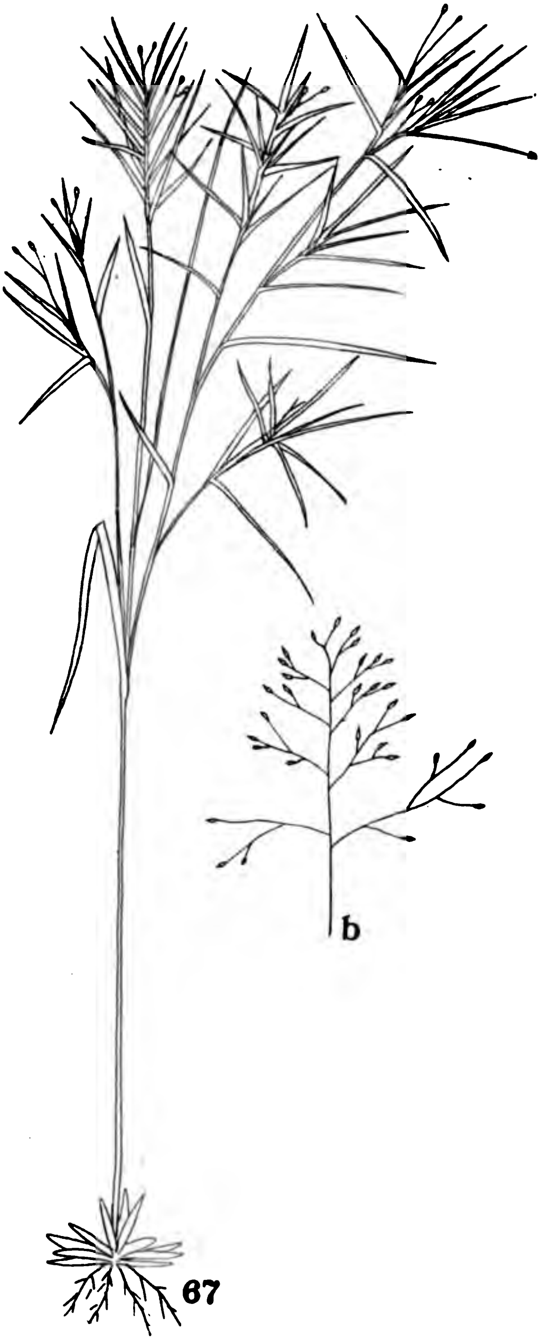
(Figs. 67 and 69)

Lapham '57, 596 (Plate 4, Fig. 4); Babcock '73, 97; Patterson '76, 52; Flagg '78, 284; Higley and Raddin '91, 139; Huett '97, 128; Hitchcock and Chase '10, 190.

Vernal culms 1 to 2 feet long, smooth and glabrous, the nodes not bearded, but sometimes, especially the lower ones, with a few hairs; sheaths less than half as long as the internodes, smooth or sparsely pubescent, leaves 2 to 4 inches long, 4 to 8 mm. wide, usually smooth but sometimes with a few long hairs along the edges; panicles borne well above the leaves, small and few-flowered; spikelets 2 mm. long, smooth, the second glume always shorter than the fruit when ripe. Autumnal culms much branched from about the middle, the lower portion usually unbranched, making the plant look like a small tree; blades much smaller than in the vernal form.

This species is often purplish in both vernal and autumnal forms. The vernal form closely resembles *P. barbulatum,* but this species has bearded nodes and the fruit is always covered by the second glume. The species described and figured by Lapham was evidently not *P. dichotomum* as it was densely pubescent, while this species is smooth.

ST. CLAIR CO. Mascoutah, *Welsch.* UNION CO. Cobden, *Waite* in 1885.



67

Fig. 67.—*P. dichotomum*, autumnal form, (b) panicle of vernal form

this group were incorrectly referred by the earlier American authors to *P. pubescens* Lam. or Michx. (that name being a synonym of *P. scoparium* Lam.). *P. pubescens*, Engelmann ('44, p. 103) is cited, but it is impossible to determine which species he collected.

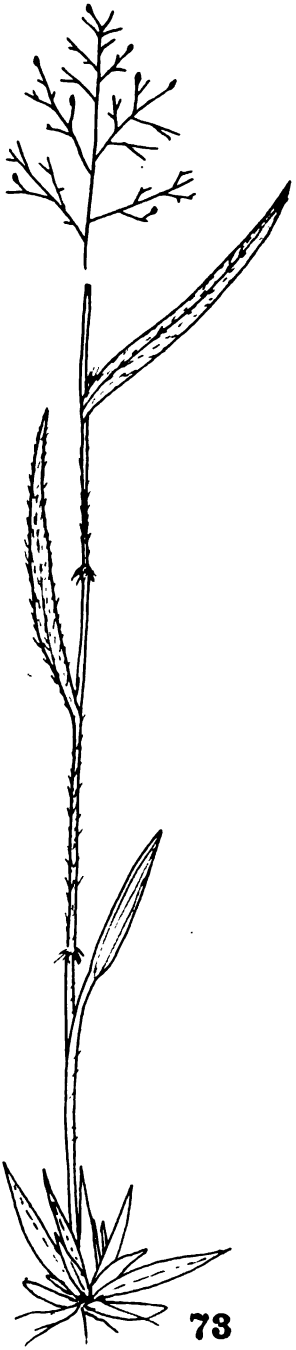


Fig. 73.—*P. huachucae*

Panicum huachucae Ashe
(Figs. 73 and 74)

Hitchcock and Chase '10, 214; Gates '12, 354.

Culms 8 to 24 inches tall, erect and stiff; culms and leaves densely papillose-pubescent; nodes bearded with spreading hairs; sheaths shorter than the internodes; blades 1.5 to 2.5 inches long, 6 to 8 mm. wide; ligules 3 to 4 mm. long; panicle axis and branches covered with long hairs nearly to the end; spikelets 1.6 to 1.8 mm. long, densely pubescent.

This species is usually light olive green but generally tinged with purple, and the spikelets are often purplish. The plant is very stiff and harsh to the touch from the abundance of hairs. The autumnal form is much the same, tho the culms are branched and the leaves much shorter; usually not much over an inch in length. The panicles are very small and almost hidden by the leaves. There is considerable variation in the amount of pubescence present. The species intergrades with the subspecies *P. huachucae silvicola,* which is apparently more abundant in Illinois.

CHRISTIAN CO. Taylorville, *Andrews,* Aug., 1898. COOK CO. East Side, Chicago, *Hill,* July, 1905; Palos Park, *Umbach,* June, 1909; Lansing, *A. Chase,* June, 1898; Beverly Hills, *A. Chase,* June, 1902; Washington Heights, *Robert Bebb,* June, 1902; Chicago, *Somes,* Aug., 1907; Chicago, *Hill* in 1905. FORD CO. Kempton, *Wilcox,* July, 1902. HENDERSON CO. Oquawka, *Patterson.* KNOX CO. Williamsfield, *V. H. Chase* 1858. LAKE CO. Beach, *Umbach* 2237, 2244; Wauconda, *Hill* in 1898; Rockefeller, *Gates,* July, 1907; area north of Waukegan, *Gates;* Waukegan, *Gleason* and *Shobe,* Aug., 1906. MACON CO. Elm Ridge, *Clokey* 2435.

PEORIA CO. Princeville, *V. H. Chase,* Aug., 1906. RICHLAND CO. Near Olney, *Ridgway.* VERMILION CO. Muncie, *Mosher,* May, 1914. WABASH CO. Without locality, *Shearer.*

Panicum huachcae silvicola Hitchc. and Chase

Hitchcock and Chase '10, 218.

This subspecies differs from the species in being taller, more slender, and not so pubescent. It is also a softer, grayer green than the species and does not look or feel so harsh. The nodes are bearded with reflexed hairs. The leaves are softer and thinner and less pubescent.

CHAMPAIGN CO. Mahomet, *Gleason* 1033; Urbana, *Gates,* Sept., 1907; Urbana, *Seymour* and *Waite* 1024; Urbana, *Mosher,* June, 1914. COOK CO. Orland, *Umbach,* Aug., 1909; Palos Park, *Umbach,* Sept., 1909; La Grange, *Hill,* July, 1907; Riverside, *Hill,* July, 1907; Englewood, *Derr,* May, 1885. DU PAGE CO. Downer's Grove, *Umbach* 1820. JACKSON CO. Makanda, *Gleason* 1028, 1030; Grand Tower, *Gleason* 1031. JO DAVIESS CO. Without locality, *Pepoon* 580 and .01. KNOX CO. Williamsfield, *V. H. Chase,* 1851. LA SALLE CO. Starved Rock, *A. Chase,* July, 1901. MACON CO. C. H. & D. Bridge, *Clokey* 2437, 2449; Decatur, *Clokey,* Aug., 1897. MCLEAN CO. Normal, *Somes* 138. MARSHALL CO. Lawn Ridge, *V. H. Chase* 1477, 1491. MENARD CO. Without locality, *Hall* in 1861; Athens, *Hall* in 1861. OGLE CO. Oregon, *Waite* in 1885; Pine Rock, *Waite,* June, 1885. PEORIA CO. Peoria, *McDonald,* Aug., 1900; Peoria, *Robert Bebb,* June, 1905; Glasford, *Wilcox* 42; Peoria, *Brendel;* Princeville, *V. H. Chase* 81. PIATT CO. White Heath, *Mosher,* July and Oct., 1914. RICHLAND CO. Parkersburg, *Ridgway,* June, 1902. ST. CLAIR CO. Mascoutah, *Welsch.* VERMILION CO. Muncie, *Mosher,* Oct., 1914. WABASH CO. Without locality, *Schneck,* July, 1897; without locality, *Shearer,* June, 1899; Hanging Rock, *Ashe* and *Schneck,* July, 1899; Mt. Carmel, *Schneck,* July, 1888; Patton, *Schneck,* June, 1879.

Panicum implicatum Scribn.
(Fig. 75)

Hitchcock and Chase '10, 213.

Vernal form with slender culms, 8 to 20 inches tall; culms and sheaths papillose-pubescent; sheaths shorter than the internodes; ligules 4 to 5 mm. long; blades 1 to 2.5 inches long, 3 to 6 mm. wide, with long, spreading pubescence, 3 to 4 mm. long, on the upper surface and shorter pubescence on the lower; panicles small, the axis with long, soft hairs, the branches usually tangled; spikelets 1.5 mm. long, densely pubescent. Autumnal form much branched from the nodes, forming small tufts of leaves, which partially conceal the much reduced panicles; culm leaves seldom over an inch long and 2 to 4 mm. in width.

This species is found in wet meadows, bogs, and swamps. It is a northern species and so far has been found only in the northern half of the state. It closely resembles *P. huachucae* as to general appearance and habit of growth.

COOK CO. Chicago, *Nelson* 66. IROQUOIS CO. Chebanse, *Hill,* July, 1870. MASON CO. Manito, *Wilcox* 57. OGLE CO. Without locality, *Waite* in 1885. ROCK ISLAND CO. Near Rock Island, *McDonald,* Sept., 1901.

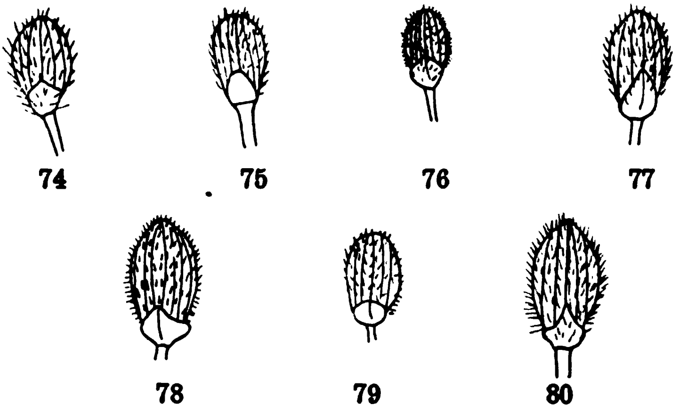
Panicum meridionale Ashe
(Fig. 76)

Hitchcock and Chase '10, 210.

Vernal form with slender culms 6 to 15 inches tall; culms and sheaths pilose; nodes bearded; sheaths shorter than the internodes; blades .5 to 1.5 inches long, 2 to 4 mm. wide, sparsely long pubescent on the upper surface and short pubescent on the lower; panicle small, the axis smooth or short pubescent; spikelets 1.3 to 1.4 mm. long, densely pubescent. Autumnal form much branched from all the nodes, the branches forming small tufts; leaves and panicles not very much reduced; panicles hidden by the leaves.

This species is found in sandy woods or shady places, in sterile soil in the woods, or in peat soil on the prairie. It closely resembles *P. implicatum* but the culms are shorter and more slender and the plants less pubescent.

COOK CO. Chicago, *Hill* 145. Kensington, *Hill,* July, 1890; Irondale, Chicago, *Hill,* July, 1913. KANKAKEE CO. South of Kankakee, *Hill,* July, 1913.



Figs. 74–80.—Spikelets: 74, *P. huachucae;* 75, *P. implicatum;* 76, *P. meridionale;* 77, *P. praecocius;* 78, *P. pseudopubescens;* 79, *P. tennesseense;* 80, *P. villosissimum*

Panicum praecocius Hitchc. and Chase
(Fig. 77)

Hitchcock and Chase '10, 226.

Vernal form with rather stout culms, 6 to 24 inches tall, often forming spreading tufts; culms and sheaths densely long pubescent; sheaths much shorter than the internodes; ligules 3 to 4 mm. long; blades 2 to 4 inches long, 4 to 6 mm. wide, long pubescent on both surfaces, the hairs nearly equal to the width of the blade; spikelets 1.8

to 1.9 mm. long, densely pubescent. Autumnal form much branched at the nodes, the branches closely appressed to the stem; leaves only slightly smaller than in the spring form, and partially concealing the much reduced panicles.

This species is found on dry prairie and in clearings. It has been found only in the middle western states. The type locality for the species is Wady Petra in Stark county.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Champaign, *Waite*, June, 1886; Urbana, *Seymour*, May, 1880. JO DAVIESS CO. Hanover, *Gleason* and *Gates*, June, 1908; without locality, *Pepoon* .02 and .04. KNOX CO. Williamsfield, *V. H. Chase* 1850. LAKE CO. Winthrop Harbor, *Gates* 2778; Waukegan, *Gates* 2469. LA SALLE CO. Starved Rock, *A. Chase* 1605. MARSHALL CO. Without locality, *V. H. Chase*, 1791. MASON CO. Havana, *Gleason* 1034. STARK CO. Wady Petra, *V. H. Chase* 472, 649, 1212, 1214, 1218. WILL CO. Joliet, *Hill* in 1907.

Panicum pseudopubescens Nash

(Fig. 78)

Panicum sp., Gleason '07, 181. *P. pseudopubescens*, Gleason '10, 147; Hitchcock and Chase '10, 235.

Vernal form with stiff culms 8 to 20 inches tall; culms and sheaths densely pubescent, the hairs usually as long as the width of the culm; nodes densely bearded with spreading hairs; sheaths shorter than the internodes; ligule about 2 to 3 mm. long; blades 2 to 4 inches long, 5 to 10 mm. wide, the upper surface long pubescent near the edge, smooth in the center, occasionally smooth all over, the lower surface with short, fine pubescence; spikelets 2.2 to 2.4 mm. long, densely pubescent. Autumnal form usually with spreading culms, sometimes flat on the ground, with a few branches at each node; leaf blades considerably reduced and usually smooth.

This species is usually light olive green in color. It is found in sandy soil, often in open woods. Gleason found it very abundant in the sand areas which he studied. There it formed one of the characteristic bunch grasses where the sand was being continually blown away from the roots of the plants.

JO DAVIESS CO. Hanover, *Gleason* and *Gates* 2535, 2539, 2575. LA SALLE CO. Starved Rock, *A. Chase* 1605; Starved Rock, *Skeels*, May, 1905.

Panicum tennesseense Ashe

(Fig. 79)

Hitchcock and Chase '10, 218.

Vernal form 10 to 25 inches tall, stiffly erect or slightly spreading; culms and sheaths with short hairs, sometimes nearly smooth; ligules 4 to 5 mm. long; nodes bearded; sheaths shorter than the internodes; blades 2 to 3.5 inches long, 5 to 8 mm. wide, with a very narrow white margin, upper surface with a few long hairs near the base, the lower surface short appressed pubescent; spikelets 1.6 to 1.7 mm. long, densely pubescent. Autumnal form usually spreading, the culms much branched at the nodes, forming tufts of leaves, often bending the plant to the ground; leaves much reduced and concealing the very small panicles.

This species is usually found in moist places. In general appearance it is much like *P. huachucae* and its subspecies, but in *P. tennesseense* the upper surface of the leaves is not pubescent. Hitchcock and Chase cite some intergrading specimens in which a few hairs occur on the upper blade surface. The plants often have a purplish tinge.

CHRISTIAN CO. Taylorville, *Andrews*, June, 1899. LAKE CO. Zion City, *Hill*, Aug., 1905; Waukegan, *Gates*, June, 1908; Beach, *Umbach*, July, 1909. ROCK ISLAND CO. Banks of Mississippi near Rock Island, *McDonald*, Sept., 1900.

Panicum villosissimum Nash

(Fig. 80)

Hitchcock and Chase '10, 233.

Culms in large tufts 10 to 20 inches tall, rather slender; culms and sheaths very densely long pubescent, giving them a soft, fuzzy appearance; nodes bearded; sheaths shorter than the internodes; ligule 4 to 5 mm. long; blades 2 to 4 inches long, 5 to 10 mm. wide, densely soft, appressed pubescent on both surfaces; spikelets 2.2 to 2.3 mm. long, the pubescence spreading. Autumnal form usually much branched, especially at the lower nodes, the leaves closely appressed to the stem, the plants often prostrate; blades not much reduced, usually with a few long hairs on the upper surface.

This species is found in dry, usually sandy soil, in open woods or on hillsides. The vernal form is light olive green; the autumnal form is often tinged with purple.

LA SALLE CO. Starved Rock, *A. Chase* 1606. MADISON CO. Without locality, *Eggert* 293.

COLUMBIANA

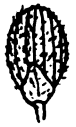
The species of Columbiana differ mainly from those of Languinosa in the absence of long, spreading hairs on culms and sheaths, the pubescence being short and appressed. The ligule is short, usually not over 1 mm. long. The blades are firm and always less than 1 cm. wide, rarely with long hairs on the upper surface. The autumnal form is freely branched. The spikelets are always covered with short pubescence.

Panicum tsugetorum Nash

(Fig. 81)

Hitchcock and Chase '10, 245.

Vernal culms 12 to 18 inches tall, usually ascending but often bent over near the base; densely pubescent with very fine, soft hairs, closely appressed; sheaths usually as long as the internodes, less pubescent than the culms, ciliate on the margin; ligules 1 to 1.5 mm. long; blades with a thin, white margin, 1.5 to 3 inches long, 4 to 7 mm. wide, usually smooth above, sometimes with a few long hairs near the base; spikelets pubescent, 1.8 to 1.9 mm. long. Autumnal form spreading on the ground and branching from the lower and middle nodes, the branches growing erect or ascending, not closely appressed to the culm; blades only slightly reduced, sometimes sparsely covered with long hairs.



81

Fig. 81.—*P. tsugetorum*, spikelet

This species is found in dry, sandy soil, usually in the woods. The type specimen was collected in a hemlock grove. The plants in spring are bluish green; later they often acquire a purplish tinge. The spikelets are usually dark colored. The general appearance of this species is like that of *P. huachucae silvicola.*

LA SALLE CO. Starved Rock, *A. Chase* 1604; Starved Rock, *Greenman, Lansing*, and *Dixon* 155. **OGLE CO.** Oregon, *Hill* in 1905.

SPHAEROCARPA

The species belonging to this group are usually found in small tufts and are practically smooth thruout. The ligules are obsolete or nearly so. The blades are rather stiff with strong margins, which are usually very rough. The panicles are usually about the length of the leaves, and are borne well above them in the spring form. This group is so named on account of the shape of the spikelets, which are almost spherical.

Panicum polyanthes Schult.

(Figs. 82 and 83)

Hitchcock and Chase '10, 254.

Vernal form with culms in a tuft 1 to 3 feet tall; culms stout, erect, smooth, scarcely ever with hairs on the nodes; sheaths as long as the internodes, smooth, ciliate on the margin; ligules too small to be distinguished; blades 5 to 10 inches long, 15 to 25 mm. wide, rough on the upper surface and smooth on the lower, except for a few hairs along the margin near the base; panicles much longer than broad; spikelets 1.5 to 1.6 mm. long, nearly spherical, short pubescent. Autumnal form much like the vernal except that a few branches with smaller blades and panicles are produced from the lower nodes.

The species listed as *P. microcarpon* by Lapham ('57, 548, 595) was probably *P. polyanthes*. The name *P. microcarpon Muhl.* 1817, not Muhl.; Ell. 1816, was then applied to the species now known as *P. polyanthes* (Hitchcock and Chase '10, 255). This species is found in damp places, usually in or near the woods. It is much taller than

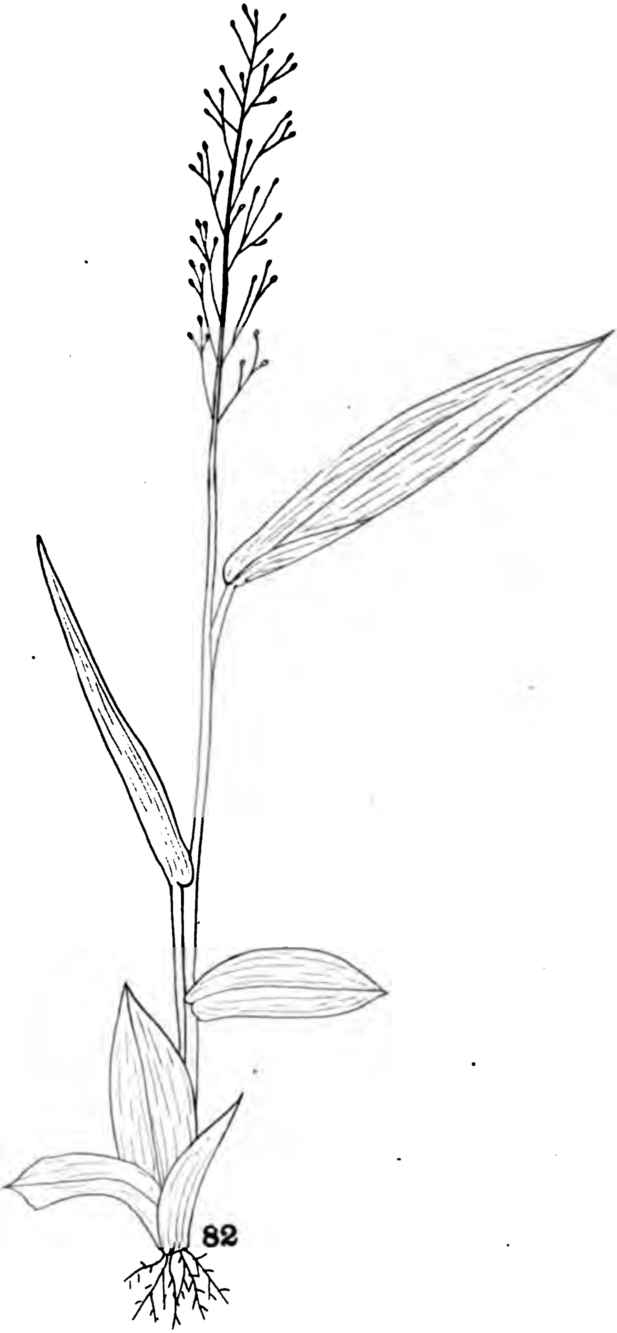


Fig. 82.—*P. polyanthes*

P. sphaerocarpon and has larger leaves. The plants are light green in color.

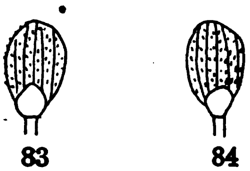
ILLINOIS SPECIMENS: Without locality, *French* in 1905. JACKSON CO. Grand Tower, *Gleason,* July, 1902. PEORIA CO. Peoria, *Brendel.* UNION CO. Cobden, *Earle* in 1886.

Panicum sphaerocarpon Ell.

(Fig. 84)

Hitchcock and Chase '10, 251.

Vernal form with culms 8 to 20 inches tall, seldom erect, the tuft usually spreading, not pubescent except on the nodes; sheaths almost as long as the internodes, slightly ciliate on the margin, otherwise smooth; ligules too small to be distinguished; blades 2 to 4 inches long, 7 to 14 mm. wide, rough but not pubescent on the upper surface except along the margin near base, smooth below; panicles about as wide as long; spikelets short pubescent, 1.6 to 1.8 mm. long, almost spherical. Autumnal form spreading on the ground, branching from the lower and middle nodes; blades and panicles not greatly reduced.



Figs. 83-84. — Spikelets: 83, *P. polyanthes;* 84, *P. sphaerocarpon*

This species is usually found in sandy soil. It is not common in Illinois. The plants are usually light green with purplish spikelets.

CHRISTIAN CO. Taylorville, *Andrews;* Aug., 1898. JACKSON CO. Without locality, *French,* June, 1878, and May, 1905.

OLIGOSANTHIA

The species belonging to this group are as a rule stout, erect plants with stiff leaves and large spikelets. The sheaths are usually hairy, the ligules never more than 1 mm. long and the spikelets 3 to 4 mm. long. In the autumnal form the culms branch near the top.

Panicum leibergii (Vasey) Scribn.

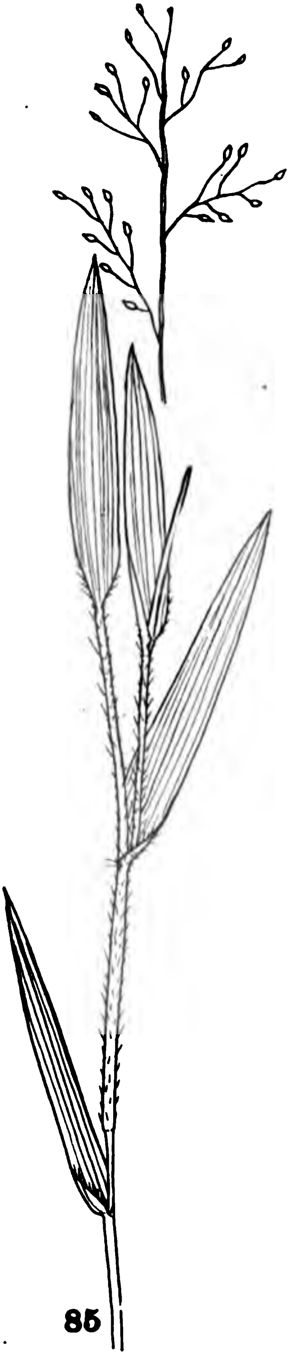
(Figs. 85 and 86)

Hitchcock and Chase '10, 289.

Vernal form with erect, slender culms in small tufts; culms 1 to 3 feet tall, usually pubescent; sheaths shorter than the internodes, conspicuously papillose-pubescent, the hairs spreading; ligules not visible; blades 2 to 6 inches long, 7 to 15 mm. wide, short, appressed papillose-pubescent on both surfaces, tho sometimes only on the basal part; panicles few-flowered, the length about twice the width; spikelets 3.7 to 4 mm. long, long pubescent. Autumnal form not very different, the culms usually leaning over, a few branches from the middle and lower nodes, the blades very little reduced, usually concealing the panicles.

This is another of the prairie species. It is found thruout the state.

CHAMPAIGN CO. Champaign, *Waite* in 1888; Champaign, *Seymour*, June, 1884. CHRISTIAN CO. Taylorville, *Andrews*, June, 1899. DU PAGE CO. Naperville, *Umbach* 1669. JO DAVIESS CO. Warren, *Pepoon* 12 and 729. KNOX CO. Without locality, *V. H. Chase* 1701. LIVINGSTON CO. Emington, *Wilcox*, July, 1902. MACON CO. Decatur, *Clokey*, May, 1889. MARSHALL CO. Near Lawn Ridge, *V. H. Chase* July, 1907. MENARD CO. Without locality, *Hall* in 1861. PEORIA CO. Peoria, *McDonald*, June, 1903. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase* 461, 1466. WILL CO. Joliet, *Skeels* 334.



85

Fig. 85.—*P. leibergii*, culm

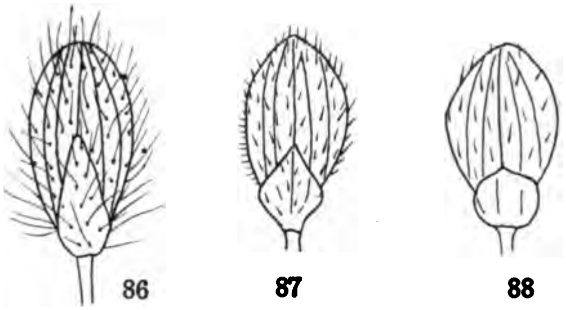
Panicum oligosanthes Schult.
(Fig. 87)

P. pauciflorum, Patterson '76, 52; Flagg '78, 284. *P. oligosanthes*, Lapham '57, 595; Hitchcock and Chase '10, 285.

Vernal form with culms in small tufts 1 to 2.5 feet tall, usually erect and finely pubescent; nodes bearded; sheaths shorter than the lower internodes, sometimes longer than the upper ones and covered with soft pubescence; ligule 1 to 2 mm. long; blades 2.5 to 5.5 inches long, 5 to 8 mm. wide, smooth except for a few hairs on the upper surface near the base; spikelets with long pedicels, 3.5 to 4 mm. long, sparsely pubescent. Autumnal form branching mostly from the upper nodes, often becoming top-heavy and lying on the ground; leaves much smaller and panicles reduced to a few spikelets.

This species is found in sandy soil usually in moist situations. The plants are olive green, very often deeply tinged with purple.

ILLINOIS SPECIMENS: Without locality, *Schneck.*



Figs. 86–88.—Spikelets: 86, *P. leibergii;* 87, *P. oligosanthes;* 88, *P. scribnerianum*

Panicum scribnerianum Nash

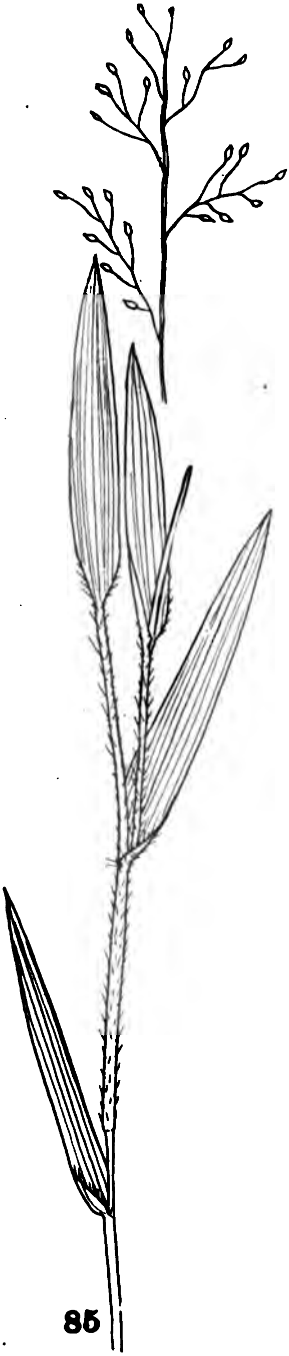
(Fig. 88)

Gleason '10, 148; Hitchcock and Chase '10, 283; Gleason '12, 48; Gates '12, 354.

Vernal form with the culms in fairly large tufts, usually somewhat spreading, 8 to 20 inches tall, generally smooth; nodes not bearded; sheaths papillose-pubescent; ligules about 1 mm. long; blades 2 to 4 inches long, 6 to 12 mm. wide, usually ciliate on the margin, sometimes with a few short hairs on the under surface, otherwise smooth; panicles small, the length and breadth about equal; spikelets 3.2 to 3.3 mm. long, sparsely pubescent or almost smooth. Autumnal form branching from the middle and upper nodes, the leaves slightly reduced, partially concealing the small panicles.

This is a typical prairie species found in dry or sandy soil. It is probably one of the commonest species of perennial Panicum found in Illinois.

CHRISTIAN CO. Taylorville, *Andrews,* June, 1899. COOK CO. Chicago, *A. Chase* 1607; Chicago, *Greenman, Lansing,* and *Dixon* 156. HENRY CO. Galva, *V. H. Chase* 1749. JO DAVIESS CO. Without locality, *Pepoon* 185; Hanover, *Gleason* and *Gates* 2598. LAKE CO. Beach, *Umbach* 2365; Waukegan, *Gates* in 1909. MACON CO. Near Decatur, *Clokey* 2438. MARSHALL CO. Without locality, *V. H. Chase* 1792. PEORIA CO. Peoria, *McDonald,* June, 1890. STARK CO. Wady Petra, *V. H. Chase* 922. VERMILION CO. Muncie, *Mosher,* May, 1914. WABASH CO. Without locality, *Shearer.*



85

Fig. 85.—*P. leibergii*, culm

pubescent on both surfaces, tho sometimes only on the basal part; panicles few-flowered, the length about twice the width; spikelets 3.7 to 4 mm. long, long pubescent. Autumnal form not very different, the culms usually leaning over, a few branches from the middle and lower nodes, the blades very little reduced, usually concealing the panicles.

This is another of the prairie species. It is found thruout the state.

CHAMPAIGN CO. Champaign, *Waite* in 1888; Champaign, *Seymour*, June, 1884. CHRISTIAN CO. Taylorville, *Andrews*, June, 1899. DU PAGE CO. Naperville, *Umbach* 1669. JO DAVIESS CO. Warren, *Pepoon* 12 and 729. KNOX CO. Without locality, *V. H. Chase* 1701. LIVINGSTON CO. Emington, *Wilcox*, July, 1902. MACON CO. Decatur, *Clokey*, May, 1889. MARSHALL CO. Near Lawn Ridge, *V. H. Chase* July, 1907. MENARD CO. Without locality, *Hall* in 1861. PEORIA CO. Peoria, *McDonald*, June, 1903. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase* 461, 1466. WILL CO. Joliet, *Skeels* 334.

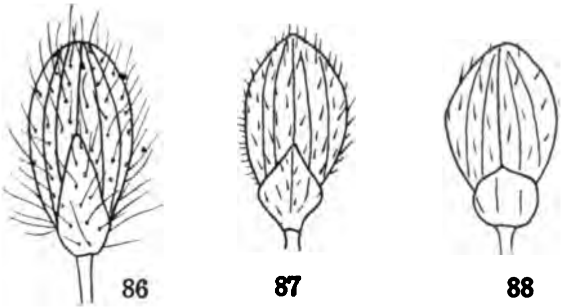
Panicum oligosanthes Schult. (Fig. 87)

P. pauciflorum, Patterson '76, 52; Flagg '78, 284. *P. oligosanthes*, Lapham '57, 595; Hitchcock and Chase '10, 285.

Vernal form with culms in small tufts 1 to 2.5 feet tall, usually erect and finely pubescent; nodes bearded; sheaths shorter than the lower internodes, sometimes longer than the upper ones and covered with soft pubescence; ligule 1 to 2 mm. long; blades 2.5 to 5.5 inches long, 5 to 8 mm. wide, smooth except for a few hairs on the upper surface near the base; spikelets with long pedicels, 3.5 to 4 mm. long, sparsely pubescent. Autumnal form branching mostly from the upper nodes, often becoming top-heavy and lying on the ground; leaves much smaller and panicles reduced to a few spikelets.

This species is found in sandy soil usually in moist situations. The plants are olive green, very often deeply tinged with purple.

ILLINOIS SPECIMENS: Without locality, *Schneck*.



Figs. 86–88.—Spikelets: 86, *P. leibergii;* 87, *P. oligosanthes;* 88, *P. scribnerianum*

Panicum scribnerianum Nash

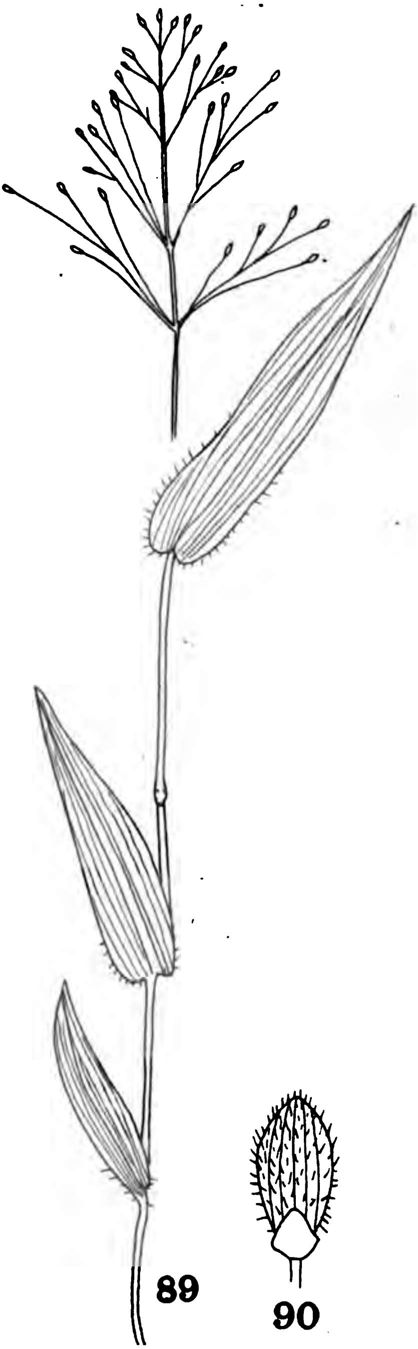
(Fig. 88)

Gleason '10, 148; Hitchcock and Chase '10, 283; Gleason '12, 48; Gates '12, 354.

Vernal form with the culms in fairly large tufts, usually somewhat spreading, 8 to 20 inches tall, generally smooth; nodes not bearded; sheaths papillose-pubescent; ligules about 1 mm. long; blades 2 to 4 inches long, 6 to 12 mm. wide, usually ciliate on the margin, sometimes with a few short hairs on the under surface, otherwise smooth; panicles small, the length and breadth about equal; spikelets 3.2 to 3.3 mm. long, sparsely pubescent or almost smooth. Autumnal form branching from the middle and upper nodes, the leaves slightly reduced, partially concealing the small panicles.

This is a typical prairie species found in dry or sandy soil. It is probably one of the commonest species of perennial Panicum found in Illinois.

CHRISTIAN CO. Taylorville, *Andrews*, June, 1899. COOK CO. Chicago, *A. Chase* 1607; Chicago, *Greenman, Lansing,* and *Dixon* 156. HENRY CO. Galva, *V. H. Chase* 1749. JO DAVIESS CO. Without locality, *Pepoon* 185; Hanover, *Gleason* and *Gates* 2598. LAKE CO. Beach, *Umbach* 2365; Waukegan, *Gates* in 1909. MACON CO. Near Decatur, *Clokey* 2438. MARSHALL CO. Without locality, *V. H. Chase* 1792. PEORIA CO. Peoria, *McDonald,* June, 1890. STARK CO. Wady Petra, *V. H. Chase* 922. VERMILION CO. Muncie, *Mosher,* May, 1914. WABASH CO. Without locality, *Shearer*.



89

90

Figs. 89-90.—89, *P. commutatum*, culm; 90, *P. commutatum*, spikelet

COMMUTATA

The species of this group are rather stout, usually with smooth culms. The blades are generally more than 1 cm. wide, smooth, and ciliate at the base. The ligule is practically wanting. The spikelets are finely pubescent, from 2.5 to 3 mm. long.

Panicum commutatum Schult.

(Figs. 89 and 90)

Hitchcock and Chase '10, 303.

Vernal form with culms in tufts, 1 to 2.5 feet high, the culms smooth; nodes occasionally with minute hairs; sheaths shorter than the internodes, usually smooth except for the ciliate margin; ligules not visible; blades short and broad, 2 to 7 inches long, 12 to 25 mm. broad, smooth on both surfaces, the margin ciliate at the base; spikelets 2.6 to 2.8 mm. long, pubescent. Autumnal form branching from the middle of the culm; the leaves little reduced; panicles very small.

This species is found mostly in woods and shady places. It is dull, grayish green, usually tinged with purple.

ILLINOIS SPECIMENS: Without locality, *Sohneck* in 1879.

LATIFOLIA

The species belonging to this group are readily distinguished by their very tall culms and broad, thin leaves, which are usually more than 1.5 cm. wide. The ligules are never over 1 mm. long. The spikelets are from 2.5 to 4.5 mm. long, short pubescent. The species are all found in shady places.

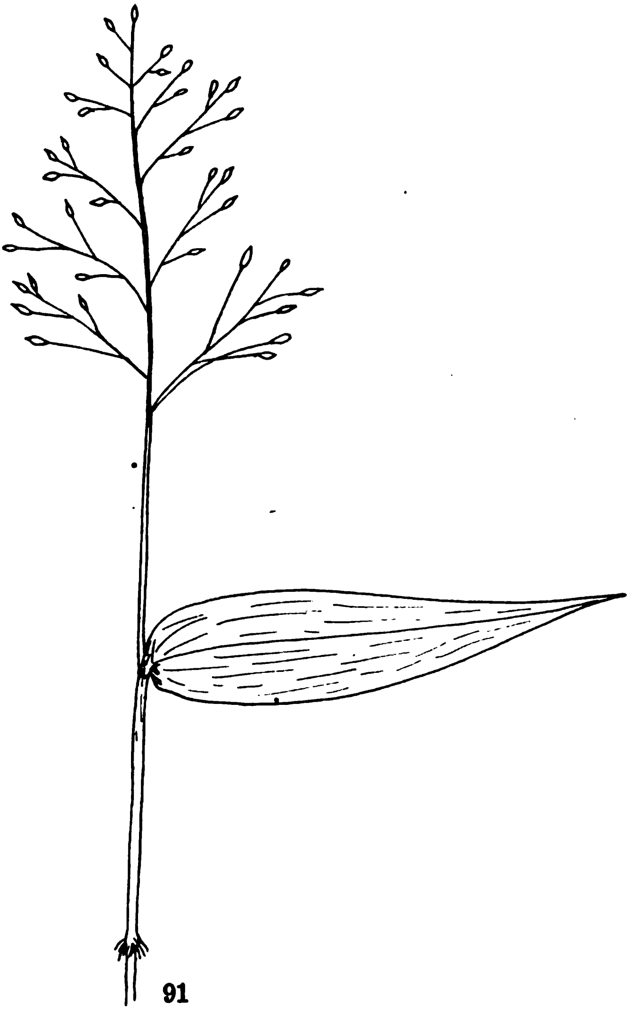


Fig. 91.—*P. boscii,* leaf and panicle

Panicum boscii Poir.

(Figs. 91 and 93)

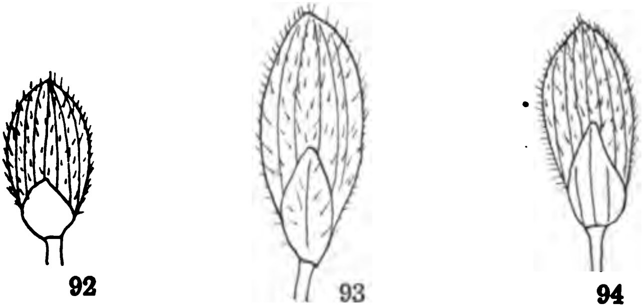
Hitchcock and Chase '10, 317.

Vernal form with the culms in large clumps 1.5 to 2.5 feet tall, usually smooth, very rarely pubescent; nodes retrorsely bearded;

sheaths a little more than half the length of the internodes, ciliate on the margin, otherwise smooth, rarely with fine pubescence; ligule about 1 mm. long; blades 2.5 to 5 inches long, 1.5 to 3 cm. wide, usually smooth on both surfaces but sometimes with a few fine, short hairs on the upper surface, ciliate on the margin at base; spikelets 4 to 4.5 mm. long, covered with fine hairs. Autumnal form as in *P. clandestinum*, sometimes branched enough to be top-heavy.

This species is found in woods and other shady places. It is closely related to *P. latifolium* and has been mistaken for that species by many of the earlier writers, who seem to have included all the species of Latifolia under that name.

CHRISTIAN CO. Taylorville, *Andrews*, May, 1899. JACKSON CO. Without locality, *French* in 1905. JOHNSON CO. Tunnel Hill, *Ridgway* in 1902. POPE CO. Herod, *Clinton*, July, 1898. ST. CLAIR CO. Mascoutah, *Welsch*. WABASH CO. Without locality, *Schneck*, May, 1906; without locality, *Shearer*, Aug., 1899; Hanging Rock, *Schneck*, Sept., 1904; Key's Hill, *Schneck*, June, 1905.



Figs. 92–94.—Spikelets: 92, *P. clandestinum;* 93, *P. boscii;* 94, *P. latifolium*

Panicum boscii molle (Vasey) Hitchc. and Chase

This differs from the species in the soft pubescence of culms and sheaths, which gives them a velvety appearance. The blades are velvety on the under surface and have slightly longer hairs on the upper surface. It is usually not so tall as the species, but there are intergrading forms.

UNION CO. Without locality, *French* in 1872. WABASH CO. Without locality, *Shearer*, Aug., 1899; Leipold's farm, *Schneck*, May, 1906; Mt. Carmel, *Schneck*, May, 1904.

Panicum clandestinum L.

(Fig. 92)

Engelmann '44, 103; Lapham '57, 548, 595; Patterson '76, 52; Flagg '78, 284; Brendel '87, 64; Higley and Raddin '91, 139; Huett '97, 128; Hitchcock and Chase '10, 312.

Vernal form with the culms in large clumps, the culms 2.5 to 5 feet tall, usually papillose-pubescent; sheaths as long as the internodes, with long hairs like the culm, at least on the lower sheaths, or on the branches; blades 4 to 8 inches long, from 1.5 to 3 cm. broad, rough on both surfaces but not pubescent, ciliate on the margin at base; spikelets 2.7 to 3 mm. long, short pubescent. Autumnal form not very different except for the branching from the middle and upper nodes, and the much reduced panicles almost completely hidden in the sheaths.

This species is found in sandy soil, usually in moist situations.

ILLINOIS SPECIMENS: Without locality, *Wolf* in 1882. CHRISTIAN CO. Taylorville, *Andrews,* May, 1898. FULTON CO. Canton, *Wolf.* JO DAVIESS CO. Along the Mississippi river, *Pepoon* 580. KANKAKEE CO. Mt. Langham, near Kankakee, *De Selm,* Sept., 1913. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* Sept., 1902 and 1903. UNION CO. Anna, *Seymour,* Aug., 1880. VERMILION CO. Stony Crest, *Butts* and *Seymour.* WABASH CO. Without locality, *Shearer;* Mt. Carmel, *Schneck,* June, 1885; Hanging Rock, *Schneck,* May, 1906; Belmont, *Schneck,* Oct., 1900.

Panicum latifolium L.

(Fig. 93)

Lapham '57, 548, 595; Babcock '73, 97; Patterson '76, 52; Flagg '78, 284; Higley and Raddin '91, 139; Huett '97, 128; Hitchcock and Chase '10, 314.

Vernal form with a clump of stout culms 1.5 to 3.5 feet tall, smooth; the nodes not bearded, rarely with a few hairs; sheaths shorter than the internodes, ciliate on the margin, otherwise smooth, or with a few short, soft hairs on the lower sheaths; ligule not visible; blades 3 to 5 inches long, 1.5 to 4 cm. wide, usually smooth, but occasionally with a few short hairs on one or both surfaces; spikelets 3.4 to 3.7 mm. long, sparsely pubescent. Autumnal form as in *P. clandestinum.*

This species is usually found in shady places. The plants are typically smooth, but some specimens are found with short hairs on culms and sheaths.

ILLINOIS SPECIMENS: Without locality, *Vasey;* without locality, *M. S. Bebb* in 1861. CHAMPAIGN CO. Urbana, *Waite* in 1886; Urbana, *Butts* and *Seymour,* June, 1880. CHRISTIAN CO. Taylorville, *Andrews,* May, 1894. COOK CO. Beverly Hills, *Robert Bebb* 882; Edgewater, Chicago, *Gates,* July, 1906; Hyde Park, Chicago, *Babcock,* July, 1873. JO DAVIESS CO. Without locality, *Pepoon,* Aug., 1908. LAKE CO. Antioch, *Gleason* and *Shobe* 268. MCHENRY CO. Algonquin, *Nason.* MACON CO. East of Fishing Club, *Clokey* 2436. MARSHALL CO. Lawn Ridge, *V. H. Chase,* July, 1907. MENARD CO. Without locality, *Hall* in 1861. PEORIA CO. Peoria, *Brendel;* Glasford, *Wilcox* 22, 41; Mossville, *A. Chase* 889; Peoria, *McDonald* 33. ST. CLAIR CO. Without locality, *Eggert* 239; Mascoutah, *Welsch.* VERMILION CO. Muncie, *Mosher,* May, 1914. WABASH CO. Without locality, *Schneck* in 1879; Key's Hill, *Schneck,* June, 1905; Mt. Carmel, *Schneck* in 1878 and Aug., 1900; Hanging Rock, *Schneck* in 1879.

The following species cited as having been found in Illinois have not been seen:

Panicum laxiflorum Lam.—This name is listed by Higley and Raddin ('91, 139) and Huett ('97, 128). It probably refers to *P. dichotomum,* while the name *P. dichotomum* was applied to the species of Languinosa.

Panicum nitidum Lam.—This name is listed by Huett ('97, 128) as occurring in Illinois. According to Hitchcock and Chase this species is not found so far north. The name may refer to *P. sphaerocarpon.*

Panicum pubescens Lam.—This is cited by Engelmann ('44, 103) and refers to the group Languinosa, the name *P. pubescens* having been applied to these species in common.

Panicum scoparium.—Englemann ('44, 103) cites *P. scoparium* Lam., while Lapham ('57, 548) cites *P. scoparium* Michx. The species they referred to is probably *P. scribnerianum.*

Panicum xanthophysum A. Gray.—Lapham ('57, 548, 595) and Flagg ('78, 284) cite this as an Illinois species. The name was probably misapplied to *P. leibergii.*

10. ECHINOCHLOA Beauv.

This genus is closely related to Panicum. It has the same type of spikelets, but the sterile lemma is awned or awn-pointed, and sometimes the second glume. The spikelets have stiff, bristly hairs on the nerves. The plants are coarse, rank annuals with long, broad leaves. The ligule is obsolete. The inflorescence is of panicles with short raceme-like branches, the spikelets crowded.

Sheaths smooth; awns seldom an inch in length, usually much shorter.
  Spikelets nearly always awned, the second glume with a short awn or awn-pointed; spines on the nerves stout and strong; panicle usually spreading, never compact, usually more than an inch in width. *E. crus-galli*
  Spikelets with a very short awn or awn point, second glume not awned or awn-pointed; spines on the nerves delicate; panicle never spreading, very compact, an inch or less in width. *E. frumentacea*
Sheaths, at least the lower, papillose-hispid; awns usually about two inches in length. *E. walteri*

Echinochloa crus-galli (L.) Beauv.

Barnyard Grass. Cock-spur Grass (Figs. 98 and 99)

Panicum crus-galli, Lapham '57, 548, 596; Babcock '73, 97; Patterson '76, 52; Flagg '78, 284; Brendel '87, 64; Higley and Raddin '91, 139; Huett '97, 128. *Echinochloa crus-galli,* Gates '12, 354; Sherff '13, 594.

Culms branching from the base, often spreading over the ground, 1 to 6 feet long; sheaths and blades smooth, the blades 6 to 24 inches long, 6 to 25 mm. wide; panicle 4 to 12 inches long, usually spreading; spikelets about 3 mm. long.

This species was introduced from Europe and is found all over the state. It is one of the commonest weeds of the farm and garden, preferring damp, rich soil, and hence it is usually abundant in barnyards. The panicles vary in color from green to purple. It can be eradicated by a thoro cultivation, which prevents the formation of seed.

ILLINOIS SPECIMENS: Without locality, *Vasey.* CHAMPAIGN CO. Urbana, *Clinton,* Aug., 1895; Urbana, *Seymour,* June, 1880; Urbana, *Mosher,* Oct., 1913. COOK CO. Bowmanvil, Chicago, *Gates,* July, 1906; Chicago, *Babcock,* Aug., 1874. FULTON CO. Canton, *Wolf.* KANKAKEE CO. Kankakee, *De Selm,* Aug., 1913. LAKE CO. Libertyville, *Sherff,* Sept., 1912; Waukegan, *Gleason* and *Shobe* 320. MCHENRY CO. Algonquin, *Nason,* Aug., 1878. MACON CO. Decatur, *Clokey,* Aug., 1897. PEORIA CO. Peoria, *McDonald;* Peoria, *Brendel.* ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. Without locality, *V. H. Chase* 95. WINNEBAGO CO. Fountaindale, *M. S. Bebb.*

Echinochloa frumentacea (Roxb.) Link

Japanese Barnyard Millet. Billion Dollar Grass (Figs. 95 and 96)

This species was introduced into the United States some years ago, in the hope that it would prove to be a valuable forage plant. As its value was not so great as was expected, little of it is now cultivated. It has frequently been found as an escape from cultivation. It closely resembles the short-awned forms of *E. crus-galli*, but has a narrower, more compact panicle.

VERMILION CO. Bank of Butler Branch creek, Catlin, *Lansing*, Sept., 1912.

Echinochloa walteri (Pursh) Nash

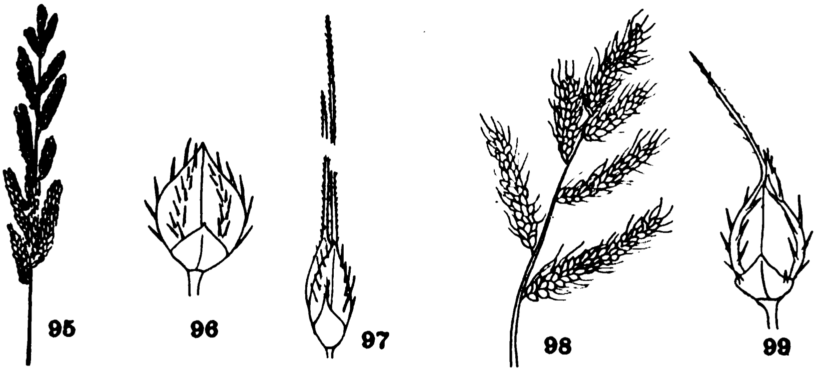
Salt-marsh Cockspur Grass (Fig. 97)

Panicum hispidum, Lapham '57, 548. *Panicum crus-galli* var. *hispidum*, Patterson '76, 52; Flagg '78, 284; Higley and Raddin '91, 139; Huett, '97, 128.

Culms branching from the base and often spreading, 1 to 6 feet long; sheaths, at least the lower, densely papillose-hirsute; blades usually roughened but not pubescent, a foot or more long, 12 to 25 mm. wide; panicle nodding, the branches usually ascending; spikelets about 3 mm. long, the first glume with a short awn, the second glume and sterile lemma with awns 2 inches or more long.

This is the only native species of the genus found in Illinois. It likes wet places, such as marshes, and is usually found near salt water.

COOK CO. Shores of Calumet lake, Chicago, *A. Chase* 1426; shores of Calumet lake, Chicago, *Sherff*, Sept., 1912; Pullman, *Hill*, Aug., 1900. FULTON CO. Canton, *Wolf*. LAKE CO. Antioch, *Gleason* and *Shobe* 259; Fox lake, Aug., 1908. PEORIA CO. Peoria, *Brendel*. ST. CLAIR CO. Without locality, *Eggert*, Sept., 1879; Mascoutah, *Welsch*; East St. Louis, *Eggert*, June, 1878. TAZEWELL CO. East Peoria, *McDonald*, Aug., 1889.

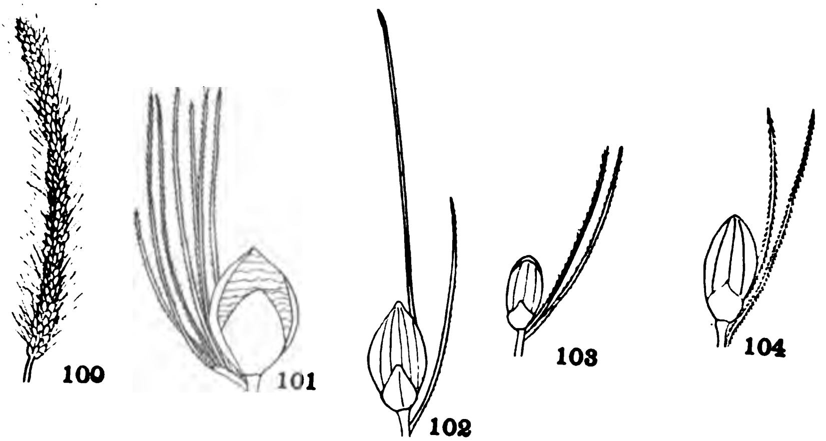


Figs. 95–99.—95, *E. frumentacea*, inflorescence; 96, *E. frumentacea*, spikelet; 97, *E. walteri*, spikelet; 98, *E. crus-galli*, inflorescence; 99, *E. crus-galli*, spikelet

11. CHAETOCHLOA Scribn.

This is another genus closely related to Panicum and with the same type of spikelets, but these have a cluster of one to several bristle-like branchlets on the short pedicel just below the spikelet (Fig. 101). The inflorescence is of spike-like panicles; the blades are long and flat. The ligule is a ring of hairs 1 to 2 mm. in length. The Illinois species are all annuals and were all introduced from Europe.

Spikelets at least 3 mm. long.
  Lemmas deeply transversely rugose, very convex; bristles 5 or more, yellow or yellowish brown; panicle 1 cm. or less thick; spikelets usually exceeding 3 mm. in length. *C. lutescens*
  Lemmas faintly transversely rugose, moderately convex; bristles 1 to 3, usually purple, but sometimes yellow; inflorescence generally more than 1 cm. thick. *C. italica*
Spikelets about 2 mm. long.
  Bristles downwardly barbed. *C. verticillata*
  Bristles upwardly barbed. *C. viridis*



Figs. 100–104.—100, *C. lutescens*, inflorescence; 101, *C. lutescens*, spikelet; 102, *C. italica*, spikelet; 103, *C. viridis*, spikelet; 104, *C. verticillata*, spikelet

Chaetochloa italica (L.) Scribn.

Millet. Hungarian Grass. Italian Millet. Foxtail Millet (Fig. 102)

Setaria italica, Flagg '78, 284; Higley and Raddin '91, 140; Huett '97, 129.

Culms generally erect, 2 to 6 feet tall; sheaths and blades generally roughened but not pubescent; blades 6 to 12 inches in length, 6 to 36 mm. wide; panicle 1.25 to 5 cm. thick, usually compound; spikelets about 3 mm. long, bristles 2 or 3, usually purplish.

This grass is extensively cultivated for forage. There are many varieties. Hungarian grass is a form with small purple heads. The common millet with a large compound inflorescence is more generally cultivated.

CHAMPAIGN CO. Urbana, *Clinton*, Aug., 1895; Urbana, *Seymour*, July, 1880; Urbana, *Mosher* in 1914. COOK CO. Chicago, *A. Chase* 1198. KANKAKEE CO. Kankakee, *Beecher*, July, 1908; Kankakee, *Hill*, Aug., 1870. LAKE CO. Channel lake, *Haynes*, Aug., 1905. PEORIA CO. Peoria, *McDonald*, July, 1900; Peoria, *Brendel*. WABASH CO. Mt. Carmel, *Schneck*, July, 1905.

Chaetochloa lutescens (Wiegel.) Stuntz

Yellow Foxtail. Pigeon Grass (Figs. 100 and 101)

Setaria glauca, Lapham '57, 548, 597 (Plate 4, Fig. 5); Patterson '76, 52; Flagg '78, 284; Higley and Raddin '91, 140; Huett '97, 129; Gleason '10, 148. *Chaetochloa glauca*, Britton '07, 89.

Culms branching at the base, usually erect, or often spreading, 1 to 4 feet long; sheaths and blades smooth, the blades 2 to 6 inches long, 5 to 15 mm. wide; panicle 1 to 3.5 inches long, 1 cm. or less wide; spikelets 3 mm. or more in length, bristles 5 or more, tawny yellow, upwardly barbed.

Yellow foxtail is one of the worst weeds of the cornfield, or in fact of most grain fields. It comes up in the field after cultivation has been discontinued and produces enormous quantities of seed, which effectively seed the field for spring. If the field is plowed in the fall before the seed ripens, and thoroly cultivated the next year, a great deal of it will be destroyed. It blooms almost thruout the season and can be eradicated only by frequent cultivation. Not all the seed sprouts the first year; the soil is often so full of it that it takes several years to eradicate it.

ILLINOIS SPECIMENS: Without locality, *M. S. Bebb* in 1868. CHAMPAIGN CO. Without locality, *Percival*, Nov., 1876; Urbana, *Gibbs*, Sept., 1898; Urbana, *Clinton*, Aug., 1895; Urbana, *Seymour*, July, 1881; Urbana, *Burrill*, Aug., 1880; Seymour, *Tsou*, Oct., 1913; Urbana, *Mosher*, Oct., 1913. COOK CO. Chicago, *Lansing*, Aug., 1897; Chicago, *Hill*, July, 1895. LAKE CO. Channel lake, *Haynes*, Aug., 1905. MACOUPIN CO. Carlinville, *Robertson* in 1881. PEORIA CO. Peoria, *Brendel*. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase*.

Chaetochloa verticillata (L.) Scribn.

Bristly Foxtail (Fig. 104)

Setaria verticillata, Patterson '76, 52; Higley and Raddin '91, 140.

Culms erect or spreading, 1 to 3 feet long; sheaths smooth; blades thin, roughened on the upper surface but not hairy; panicles much like those of *C. lutescens* as to shape and size, green; spikelets 2 to 2.5 mm. in length, bristles 1 to 3, stout, and downwardly barbed.

This species is a weed in waste places and around dwellings, but it is not very common in Illinois.

HENDERSON CO. Oquawka, *Patterson*, Sept., 1873. PEORIA CO. Peoria, *Brendel*. ROCK ISLAND CO. Moline, *Seymour*, Aug., 1884. STARK CO. *V. H. Chase*, Aug., 1897.

Chaetochloa viridis (L.) Scribn.

Green Foxtail. Bottle Grass (Fig. 103)

Setaria viridis, Vasey '61, 671; Patterson '76, 52; Flagg '78, 284; Higley and Raddin '91, 140; Huett '97, 129; Gleason '07, 181.

Culms branching at the base, erect or spreading, 1 to 3 feet tall; sheaths and blades smooth, the blades 3 to 10 inches long, 4 to 12 mm. wide; panicles less than 1 cm. broad; spikelets about 2 mm. long, bristles 1 to 3, green, upwardly barbed.

Green foxtail is found in the same places as yellow foxtail, *C. lutescens*, and may be exterminated in the same way.

CHAMPAIGN CO. Urbana, *Clinton*, Aug., 1895; Champaign, *Gibbs*, Oct., 1898; Urbana, *Seymour*, June, 1880; Urbana, *Mosher*, Oct., 1913. CHRISTIAN CO. Taylorville, *De Motte*. COOK CO. Hyde Park, Chicago, *A. Chase*, July, 1901; Landers, Chicago, *Hill*, July, 1895. KANKAKEE CO. Waldron, *Hill*, July, 1873. MCHENRY CO. Algonquin, *Nason*, Aug., 1878. MACOUPIN CO. Carlinville, *Robertson*, Aug., 1882. PEORIA CO. Peoria, *McDonald*; Peoria, *Brendel*. STARK CO. Wady Petra, *V. H. Chase*, Aug., 1897. WABASH CO. Without locality, *Schneck*, May, 1896.

12. CENCHRUS L.

Because of the peculiar burs which inclose the spikelets, the plants belonging to this genus will never be confused with any other species of grass. These burs are borne in a spike and are armed with stout spines which are retrorsely barbed and often inflict painful wounds. They are easily detached from the culm when they are mature and are carried around by animals. Each bur contains from 2 to 6 spikelets which always remain and germinate inside the bur. The sheaths are rather loose and the blades are short and narrow. The ligule is a ring of short hairs less than 1 mm. in length. The plants are found in waste places, usually where there is sandy soil. The only species in Illinois is an annual.

Cenchrus carolinianus Walt.

Sandbur. Bur Grass. Hedgehog Grass (Figs. 105 and 106)

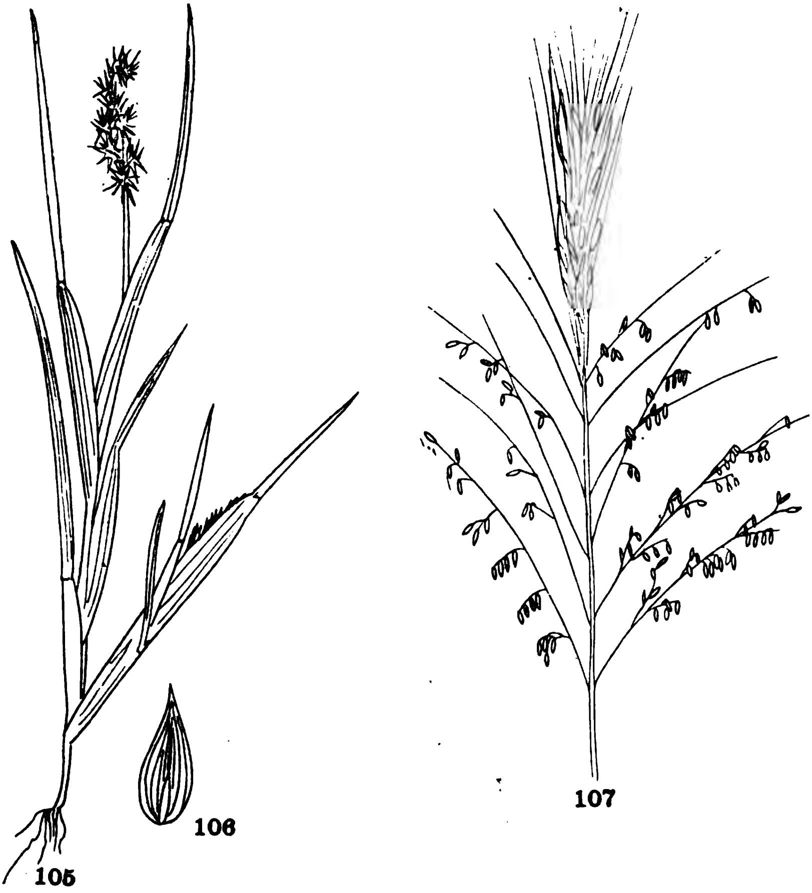
Cenchrus tribuloides, Lapham '57, 548, 597; Flagg '78, 284; Brendel '87, 64; Higley and Raddin '91, 140; Huett '97, 129; McDonald '00, 103. *Cenchrus carolinianus*, Gleason '10, 148; Gates '12, 354.

Culms flattened, 8 to 30 inches long, branched at nearly all the nodes, usually spreading on the ground, the branches ascending, and forming large mats; sheaths loose, flattened, smooth; blades smooth, sometimes folded, 2 to 5 inches long, 5 to 10 mm. broad; burs about 8 mm. thick, the surface pubescent between the spines.

This species is a troublesome weed in some situations, but it may be eradicated by thoro cultivation.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CARROLL CO. Near Mississippi river, *Pepoon*, Aug., 1879. CHAMPAIGN CO. Champaign, *Gibbs*, Oct., 1898; Champaign, *Seymour*, Sept., 1880. COOK CO. Chicago, *Lansing*; Chicago, *Babcock*, July, 1874; Ravenswood, *Reynolds*. KANKAKEE CO. Altorf, *Hill*, July, 1873.

LAKE CO. Waukegan, *Gates* 2980. MCHENRY CO. Ringwood, *Vasey*. MACOUPIN CO. Carlinville, ***Robertson***, Aug., 1881. MASON CO. Without locality, ***M. S. Bebb*** in 1861. MENARD CO. Without locality, *Hall;* Athens, *Hall*, Aug., 1864. PEORIA CO. Peoria, ***McDonald***, Aug., 1885; Peoria, ***Brendel***, Aug., 1852. STARK CO. Wady Petra, ***V. H. Chase*** 1929. VERMILION CO. Muncie, ***Mosher***, Oct., 1915. WINNEBAGO CO. Fountaindale, ***M. S. Bebb***. WABASH CO. Banks of Wabash river, *Schneck*, July, 1904.



Figs. 105–107.—105, *C. carolinianus;* 106, *C. carolinianus*, spikelet; 107, *Z. palustris*, inflorescence

13. ZIZANIA L.

These annual grasses are usually found growing in the water along the edges of ponds and streams. The plants are tall, with broad leaves and large, open panicles. The erect, awned, pistillate spikelets are borne on the ascending upper branches of the panicle, the pendulous, staminate spikelets on the spreading lower branches. The spikelets are all one-flowered.

Zizania palustris L.

Wild Rice. Water Oats. Indian Rice (Fig. 107)

Zizania aquatica, Lapham '57, 544, 561 (Plate 1, Fig. 2); Babcock '73, 96; Patterson '76, 49; Flagg '78, 279; Brendel '87, 63; Higley and Raddin '91, 140; Huett '97, 129; Cowles '00, 155.

Culms erect, 3 to 10 feet tall; sheaths loose, smooth; ligule membranous, 5 to 6 mm. long; blades 1 to 3 feet long, 1.5 to 4 cm. wide, smooth; panicles 1 to 2 feet long; pistillate spikelets 8 to 24 mm. long, awned; staminate, 6 to 12 mm. long, not awned.

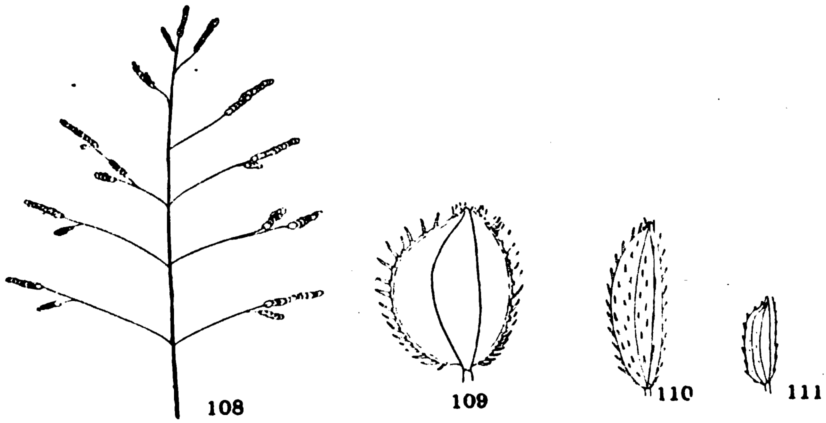
This species was once very abundant in Illinois but is now rare. Patterson '76 describes it as being very common along the margins of ponds and sloughs. Mr. R. E. Richardson of the Illinois State Laboratory of Natural History, who is stationed at Havana, says that from inquiries he has made there seems to be no doubt that prior to 1900 wild rice was abundant along the Illinois river as far north as the head of Peoria lake. In that year the permanent increase in water levels caused by the addition of water from Lake Michigan probably led to its extermination in many situations, tho it is reported to be still found along Rice lake and Beebe lake. Mr. Elmer Caldwell, formerly a member of the State Fish Commission, has reported it from his land around Slim lake and Moulden lake, which are not far from West Matanzas lake. One of the old residents of Havana reports that in the '90's a Mr. Thomas High used to cut it regularly for hay on his land about Duck lake.

COOK CO. Chicago, *Babcock*, Aug., 1874; Desplains river, Lyons, *A. Chase*, Aug., 1901; Thornton, *Hill*, Sept., 1866. DU PAGE CO. Hinsdale, *Smith*, Sept., 1902. FULTON CO. Canton, *Wolf;* Breeds, *Clinton*, Aug., 1897. KANKAKEE CO. In Kankakee river, *Hill*, Aug., 1870. LAKE CO. Fourth lake, *Walcott*, Aug., 1911. MCHENRY CO. Ringwood, *Vasey*. PEORIA CO. Peoria, *Brendel*. UNION CO. Bluff lake, *Seymour*. WILL CO. Joliet, *Skeels*, Aug., 1904.

14. **HOMALOCENCHRUS** Mieg.

These grasses are found in wet, usually marshy places and are easily distinguished by their panicles of laterally flattened spikelets, their narrow, rough leaves, and very short membranous ligules. The spikelets are perfect, the glumes obsolete. There are two kinds of panicles, however,—a broad, spreading one, in which the spikelets are usually sterile, and a small, narrow, hidden one inclosed by the sheath, in which the spikelets ripen seed. The species are all native to Illinois.

Spikelets longer than broad, with bristly hairs on the margins and veins, the surface pubescent.
  Spikelets 2.5 to 3.5 mm. long, sparsely covered with short, stiff hairs all of the same length; branches single. *H. virginicus*
  Spikelets 4 to 5 mm. long, with longer, stiffer hairs around the margin; branches fascicled. *H. oryzoides*
Spikelets about as broad as long, with strong, bristly hairs on margins and veins, the surface smooth and glabrous. *H. lenticularis*



Figs. 108–111.—108, *H. lenticularis*, inflorescence; 109, *H. lenticularis*, spikelet; 110, *H. oryzoides*, spikelet; 111, *H. virginicus*, spikelet

Homalocenchrus lenticularis Michx.

Catch-fly Grass (Figs. 108 and 109)

Leersia lenticularis, Michaux '03, 39; Lapham '57, 544, 560; Patterson '76, 49; Flagg '78, 279; Brendel '87, 63.

Culms 2 to 4 feet tall, smooth, usually not branched, the nodes pubescent; sheaths rough, blades slightly rough, 4 to 12 inches long, 8 to 20 mm. wide; panicle 4 to 10 inches long; spikelets very flat, closely overlapping and nearly covering each other, 5 mm. in length.

This species was reported by Patterson '76 as abundant along the river banks from Peoria and Henderson counties southward. In 1904 it was reported by F. E. McDonald as rare.

ILLINOIS SPECIMENS: Without locality, *Hall*. COOK CO. Wolf lake, Chicago, *Hill*, Sept., 1892. HANCOCK CO. Without locality, *Ehinger* in 1881. HENDERSON CO. Mississippi river near Oquawka, *Patterson*, Sept., 1873. KANKAKEE CO. Kankakee, *Hill*, Aug., 1870. MACON CO. Decatur, *Clokey*, Sept., 1898. MARION CO. Without locality, *M. S. Bebb*. MASON CO. Havana, *Seymour*, Aug., 1886. MENARD CO. Without locality, *Hall* in 1861; Athens, *Hall* in 1861. PEORIA CO. Near Illinois river, *McDonald* in 1904; Peoria, *McDonald*, Sept., 1901; Peoria, *Brendel*. ST. CLAIR CO. Fayetteville, *Brendel; Mascoutah, Welsch*. WILL CO. Homer, *Hill*, Aug., 1911. WOODFORD CO. Near Upper Ferry, *McDonald*, Aug., 1889.

Homalocenchrus oryzoides (L.) Sw.

Cut Grass. White Grass. False Rice. Rice Cut Grass (Fig. 110)

Leersia oryzoides, Lapham '57, 544, 560; Babcock '73, 96; Patterson '76, 49; Flagg '78, 279; Brendel '87, 63; Higley and Raddin '91, 140; Huett '97, 129; Gates '12, 354; Gleason '12, 44; Sherff '13, 594.

Culms 1 to 3 feet long, usually branched, smooth, the nodes pubescent; sheaths and blades usually quite rough, the blades 3 to 10 inches long and 4 to 10 mm. wide; spikelets 4 to 5 mm. long.

This species is usually found in the water or in very damp soil. It gets its common name from the roughness of the leaves, which often cut the hands if one attempts to pull up the plant.

ILLINOIS SPECIMENS: Without locality, *Vasey;* northern Illinois. *M. S. Bebb.* CHAMPAIGN CO. Urbana, *Seymour,* Oct., 1880; Crystal lake, Urbana, *Clinton,* Sept., 1899; Mahomet, *Gibbs* and *Clinton,* Oct., 1898. COOK CO. Evanston, *Shipman,* Sept., 1875; Chicago, *Lansing,* Sept., 1898; Palos Park, *Umbach,* Sept., 1909. DU PAGE CO. Hinsdale, *Smith,* Sept., 1902. FORD CO. Paxton, *Moffatt,* Sept., 1897. FULTON CO. Canton, *Wolf.* JACKSON CO. Makanda, *Seymour,* Aug., 1880. KANKAKEE CO. Kankakee, *De Selm,* Sept., 1913. LAKE CO. South of Lake Villa, *Gleason* and *Shobe* 228; Libertyville, *Sherff,* Sept., 1912. LIVINGSTON CO. Chatsworth, *Wilcox,* July, 1902. MCHENRY CO. Algonquin, *Nason,* Aug., 1878. MACOUPIN CO. Carlinville, *Robertson,* Aug., 1880. MARSHALL CO. Near Henry, *Meek,* Sept., 1906. MENARD CO. Athens, *Hall,* Sept., 1864. OGLE CO. Oregon, *Waite,* Aug., 1884. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* Sept., 1896, and 1904. ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase,* 1910. VERMILION CO. Butler Branch creek, Catlin, *Lansing,* Sept., 1912. WABASH CO. Hanging Rock, *Schneck;* Mt. Carmel, *Schneck,* Oct., 1876; Greathouse creek, *Schneck,* Sept., 1880. Shannon's swamp, *Schneck,* Sept., 1879. WILL CO. Without locality, *Moffatt,* Sept., 1891; Joliet, *Skeels,* Aug., 1904. WINNEBAGO CO. Fountaindale, *M. S. Bebb.*

Homalocenchrus virginicus Willd.

White Grass (Fig. 111)

Leersia virginica, Lapham '57, 544, 560 (Plate 1, Fig. 1); Babcock '73, 96; Patterson '76, 49; Flagg '78, 279; Brendel '87, 63; Higley and Raddin '91, 140; Huett '97, 129.

Culms slender, branched, 1 to 3 feet tall, smooth, the nodes pubescent and sometimes the culm for a short distance below the node; sheaths smooth, blades thin, slightly rough on both surfaces, 2 to 6 inches long, 2 to 6 mm. wide; spikelets 2.5 to 3 mm. long.

This species is often found in damp woods as well as along the margins of streams and ponds.

ILLINOIS SPECIMENS: Without locality, *Hall;* without locality, *Vasey.* CHAMPAIGN CO. Urbana, *Clinton,* Sept., 1899; Urbana, *Waite,* Aug., 1887. COOK CO. Palos Park, *Umbach,* Sept., 1909; Beverly Hills, *Robert Bebb,* Aug., 1904; Bowmanvil, Chicago, *Gates.* DU PAGE CO. Hinsdale, *Smith,* Aug., 1902. JACKSON CO. Without locality, *French,* Aug., 1905. KANKAKEE CO. Baker creek, Kankakee, *De Selm,* Sept., 1913. MCHENRY CO. Algonquin, *Nason,* Aug., 1878. MACON CO. Decatur, *Clokey,* Sept., 1898. MENARD CO. Without locality, *Hall;* Athens, *Hall* in 1864. PEORIA CO. Glasford, *Wilcox,* July, 1902; Peoria, *McDonald,* Aug., 1895; Peoria, *Brendel;* Princeville, *V. H. Chase,* Aug., 1900. ST. CLAIR CO. Without locality, *Brendel;* Mascoutah, *Welsch.* WABASH CO. Mt. Carmel, *Waite,* Aug., 1887; Mt. Carmel, *Schneck,* Aug., 1900; Hanging Rock, *Schneck,* Sept., 1879.

15. PHALARIS L.

These grasses are either annual or perennial and have laterally flattened, apparently one-flowered spikelets in which the glumes are long, exceeding the hardened lemma and palea. There are two small scales at the base of the floret which represent sterile lemmas. The leaves are flat, the ligule thin, membranous, 3 to 5 mm. long. The inflorescence is of spike-like, or very narrow panicles.

Inflorescence a contracted panicle 8 to 12 cm. long, usually about 1 cm. broad; spikelets 5 to 6 mm. long, the glumes not winged.
Leaves green; axis of the panicle rarely visible. *P. arundinacea*
Leaves striped green and white; axis of the panicle often visible, especially at the base. *P. arundinacea picta*
Inflorescence an ovate, spike-like panicle, 2 to 5 cm. long, always more than 1 cm. broad; spikelets 6 to 8 mm. long; the glumes winged. *P. canariensis*

Phalaris arundinacea L.

Reed Canary Grass (Figs. 116 and 117)

Lapham '57, 548, 591 (Plate 4, Fig. 2); Babcock '73, 97; Patterson '76, 52; Flagg '78, 284; Brendel '87, 64; Higley and Raddin '91, 141; Sherff '12, 419; Sherff '13, 594.

Culms erect, smooth, 2 to 5 feet tall; sheaths smooth; blades slightly rough, 3 to 6 inches long, 6 to 16 mm. wide; spikelets 5 to 6 mm. long.

ILLINOIS SPECIMENS: Without locality, *Vasey*. COOK CO. Chicago, *Babcock*, June, 1870 and 1873; south of Chicago, *McDonald*, June, 1890; Beverly Hills, *A. Chase*, June, 1903. DU PAGE CO. Naperville, *Umbach*, June, 1897. FULTON CO. Canton, *Wolf*. HENDERSON CO. Oquawka, *Patterson*, June, 1872. MCHENRY CO. Ringwood, *Vasey*. PEORIA CO. Peoria, *Brendel*. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Near Wady Petra, *V. H. Chase* 615. WABASH CO. Mt. Carmel, *Schneck*, May, 1900.

Phalaris arundinacea picta L.

Ribbon Grass. Painted Grass

This variety, a common garden form introduced from the Old World, is probably more familiar to many Illinois people than the native species. The leaves are striped with white, and the panicle is usually more open. It frequently escapes from cultivation.

CHAMPAIGN CO. Urbana, *Pillsbury*, June, 1889. ST. CLAIR CO. Mascoutah, *Welsch*.

Phalaris canariensis L.

Canary Grass (Figs. 114 and 115)

Lapham '57, 591; Babcock '73, 97; Flagg '78, 284; Higley and Raddin '91, 141; Huett '97, 129.

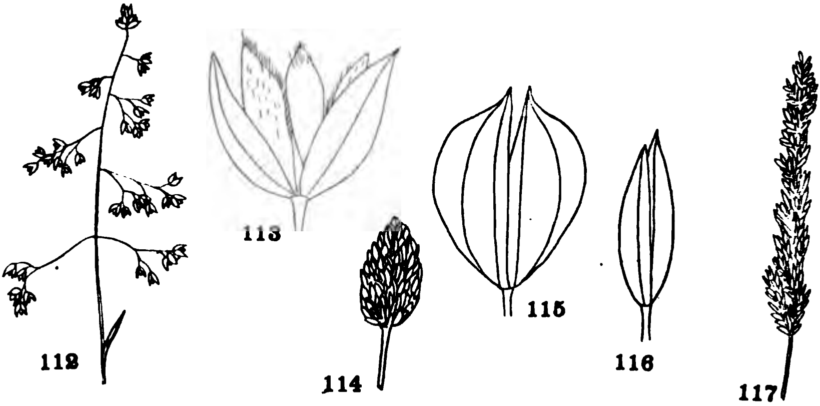
Culms erect, smooth, 1 to 3 feet tall; sheaths slightly roughened, blades very rough, 2 to 6 inches long, panicles spike-like, the length 2 or 3 times the width; spikelets 6 to 8 mm. long, white or pale yellow, the nerves green.

This species is an annual introduced from Europe. It is found in waste places and along roadsides. The seeds are used as food for canaries.

CHAMPAIGN CO. Urbana, *Seymour*, June, 1880; Champaign, *McCluer*, July, 1893. COOK CO. Chicago, *Warne;* Jackson park, Chicago, *Clark*, July, 1902. MCHENRY CO. Algonquin, *Nason*, July, 1878. MACOUPIN CO. Carlinville, *Robertson*, July, 1883. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald*, July, 1896. ST. CLAIR CO. Mascoutah, *Welsch*.

16. TORRESIA Ruiz and Pav.

The grasses belonging to this genus are perennials with long, creeping rootstocks and fragrant leaves. The spikelets are three-flowered, the terminal floret perfect, the lower ones staminate, the three falling together. The leaves are flat, the lower ones very long and narrow, the upper ones very short. The ligules are thin and membranous, 3 to 4 mm. long. The inflorescence is an open panicle and the spikelets are brown and shining. Only one species of the genus is found in Illinois.



Figs. 112–117.—112, *T. odorata,* panicle; 113, *T. odorata,* spikelet; 114, *P. canariensis,* inflorescence; 115, *P. canariensis,* spikelet; 116, *P. arundinacea,* spikelet; 117, *P. arundinacea,* inflorescence

Torresia odorata (L.) Hitchc.

Holy Grass. Vanilla Grass (Figs. 112 and 113)

Hierochloa borealis, Vasey '61, 671; Patterson '76, 52; Flagg '78, 284; Brendel '87, 88; Higley and Raddin '91, 141; Huett '97, 129. *Hierochloë odorata,* Gates '12, 355. *Savastana odorata,* Britton '07, 93.

Culms erect, smooth, 2 to 3 feet tall; sheaths smooth; blades smooth, 2 to 6 mm. wide, those at the base 4 to 8 inches long, those on the culm 1 to 2 inches long; spikelets 4 to 6 mm. long, shining brown, when fresh usually with a purplish tinge.

This grass is called Holy grass in Europe, where it is strewn before churches on saints' days. In this country the long leaves have been used by the Indians in weaving baskets, mats, etc., tho the grass which is now most used by them for this purpose is *Anthoxanthum odoratum*, or sweet vernal grass, which retains its fragrance much better. No Illinois specimens of this grass have been seen by the writer.

ILLINOIS SPECIMENS: Without locality, northern Illinois, *Brendel.* COOK CO. Without locality, *Shipman,* May, 1876; Beverly Hills, *A. Chase* 2074; Dunning, *Gates,* May, 1906; Dunning, *Umbach,* May, 1901; Chicago, *Moffatt,* May, 1895;

Chicago, *Babcock,* May, 1874; Washington Heights, *Hill,* May, 1882; South park, Chicago, *Clark,* May, 1902. DU PAGE CO. Naperville, *Umbach,* May, 1895. GRUNDY CO. Without locality, *Brendel.* LAKE CO. Beach, *Gates* 1651. MCHENRY CO. Without locality, *Vasey;* Ringwood, *Vasey* in 1853. WINNEBAGO CO. Without locality, *M. S. Bebb.*

17. MILIUM (Tourn.) L.

These grasses are distinguished by the narrow, one-flowered spikelets in which the glumes are equal and exceed the hard, shiny lemma and palea, which resemble those of species of Panicum. The leaves are thin and flat and the ligule thin and membranous, 3 to 4 mm. long. The panicle is large and open. There is one species in Illinois, which is perennial from creeping rootstocks.

Milium effusum L.

Wild Millet. Tall Millet Grass (Figs. 118 and 119)

Patterson '76, 52; Flagg '78, 284; Brendel '87, 88.

Culms erect but weak, smooth, 2 to 6 feet tall; leaves smooth thruout, the blades 3 to 9 inches long, 6 to 15 mm. wide; panicles 6 to 20 inches long, the drooping branches usually roughened with short, stiff hairs; spikelets 3 to 3.5 mm. long, the surface of the glumes rough.

This species is usually found in rich, moist woods. It is native to the northern part of America and is also found in the north of Europe and Asia.

KANE CO. Elgin, *Vasey.* TAZEWELL CO. Without locality, *Brendel.*

18. ORYZOPSIS Michx.

These perennial grasses are not abundant in Illinois. The spikelets are one-flowered, the glumes long, the lemma rather hard, pubescent, and terminated by a slender, deciduous awn. The leaves are often involute; the ligule is membranous and very short, almost wanting. The inflorescence is of very narrow panicles borne well above the leaves.

Blades narrow, involute; spikelets, excluding awn, less than 5 mm. long. *O. pungens*
Blades broad, flat; spikelets, excluding awn, always more than 5 mm. long.
  Leaves mostly crowded at the base of the plant; blades rough on the upper surface but not pubescent. *O. asperifolia*
  Leaves distributed along the culm; blades densely pubescent on the upper surface. *O. racemosa*

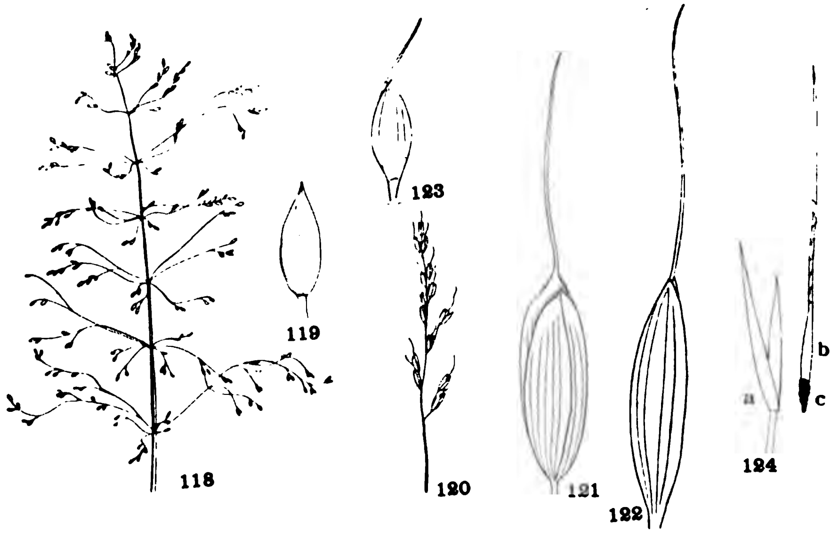
Oryzopsis asperifolia Michx.

White-grained Mountain Rice (Figs. 120 and 121)

Culms usually erect, tufted, 1 to 2 feet tall, the leaves crowded at the base; sheaths smooth; basal blades very long, often longer than the culm, generally covered with whitish bloom, rough on the upper surface but not pubescent, 4 to 8 mm. wide; culm blades, if present, less than an inch long; spikelets 6 to 8 mm. long, the awn 5 to 10 mm. long; lemma not turning black when the fruit is ripe.

This species is found on wooded hillsides or in pastures, especially in damp situations. After the fruit is ripe, the leaves usually spread out flat on the ground, while the culms remain erect.

COOK CO. Without locality, *Shipman* in 1877.



Figs. 118–124.—118, *M. effusum*, panicle; 119, *M. effusum*, spikelet; 120, *O. asperifolia*, inflorescence; 121, *O. asperifolia*, spikelet; 122, *O. racemosa*, spikelet; 123, *O. pungens*, spikelet; 124, *S. spartea*, spikelet, (a) glume, (b) lemma, (c) callus

Oryzopsis pungens (Torr.) Hitchc.
Slender Mountain Rice (Fig. 123)

Oryzopsis canadensis, Lapham '57, 545; Flagg '78, 280.

Culms in thick tufts, 6 to 30 inches tall; the leaves crowded at the base and nearly as long as the culm; sheaths usually smooth; blades narrow and involute; culm leaves, if any, very short; spikelets 3 to 4 mm. long, the awn very short or wanting.

This species is found in dry, usually rocky soil.

ILLINOIS SPECIMENS: Without locality, *Hall*. ST. CLAIR CO. Mascoutah, *Welsch*.

Oryzopsis racemosa (Sm.) Ricker
Black-fruited Mountain Rice (Fig. 122)

Oryzopsis melanocarpa, Patterson '76, 50; Flagg '78, 280; Brendel '87, 63.

Culms erect, simple, 2 to 4 feet tall, the leaves not crowded at the base; sheaths usually smooth, blades flat, 4 to 12 inches long, 4 to 15 mm. wide, rough beneath, densely pubescent above; spikelets 7 to 9 mm. long, the awn 15 to 25 mm. long; lemma black at maturity.

Usually found in rocky woods. It is quite different in appearance from either of the other species. Usually it is not found in such large tufts.

COOK CO. Glencoe, *Johnson,* Sept., 1890. PEORIA CO. Peoria, *Brendel.* ST. CLAIR CO. Mascoutah, *Welsch.*

19. STIPA L.

These species are readily recognized by the long-awned spikelets. The glumes are membranous, narrow, and acuminate. The floret terminates in a strong awn twisted at base and usually bent once or twice; at the base of the floret is a sharp-pointed callus covered with backward-pointing hairs. . The lemma is hardened, convolute, and incloses the palea. The inflorescence is a panicle. The leaves are long, narrow, and involute. The ligule is rather thick and membranous, 1 to 2 mm. long. It is probable that three species may have been found in Illinois, but authentic specimens of only one species have been seen by the writer. The species are all perennials.

Stipa spartea Trin.

Porcupine Grass (Fig. 124)

Lapham '57, 545, 569; Babcock '73, 97; Flagg '78, 280; Brendel '87, 63; Higley and Raddin '91, 141; Huett '97, 129; Gleason '07, 182; Gleason '10, 148; Gates '12, 355.

Culms erect, not branched, 2 to 9 feet tall, the leaves mostly crowded at the base; sheaths smooth, the upper sheaths often rather loose and sometimes inclosing the base of the panicle; blades long and narrow, usually involute, not over 4 mm. wide; glumes 2.5 to 3.5 cm. long, a little longer than the dark brown lemma; awn 4 to 8 inches long; callus with a needle-like point.

This is one of the species of prairie grasses. It is found all over the state.

ILLINOIS SPECIMENS: Without locality, prairies, *Vasey;* without locality, *Mead.* CHAMPAIGN CO. Champaign, *Waite,* June, 1886; Urbana, *Seymour,* June, 1880; Champaign, *Gleason*, May, 1902. COOK CO. West of Chicago, *Moffatt,* June, 1893. DU PAGE CO. Naperville, *Umbach,* May, 1899; Hinsdale, *Smith.* HENDERSON CO. Oquawka, *Patterson,* June, 1872. HENRY CO. Galva, *V. H. Chase* 1750. JO DAVIESS CO. Hanover, *Gleason* and *Gates* 2602. KANKAKEE CO. Kankakee, *Hill,* June, 1873. LAKE CO. Beach, *Gates* 2464. MCHENRY CO. Ringwood, *Vasey.* MACON CO. Decatur, *Clokey,* May, 1899. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* June, 1887. ST. CLAIR CO. Without locality, *Eggert,* May, 1877; Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase* 1206. WILL CO. Joliet, *Skeels,* June, 1904. WINNEBAGO CO. Fountaindale, *M. S. Bebb.*

Stipa avenacea L.—This species, commonly called black oat grass, appears to have been found in Illinois some time ago. Lapham ('57, 545, 569) describes it as occurring in the state and figures it (Plate 2, Fig. 1). From his description and figure it seems that the identification was correct. He describes it as occurring in dry, sandy places in timbered land and openings. It is also mentioned by Flagg ('78, p. 280). This species is distinguished from *Stipa spartea* by its smaller spikelets in which the glumes are 8 to 10 mm. long and the awn 1.5 to 3 inches long.

Stipa virdula Trin.—This species, commonly called green Stipa, is a native of the western states. In the Field Museum, Chicago, there is a specimen collected by E. Hall, Athens, 1862. Hall brought many seeds of western grasses back with him and planted them in Athens, and many specimens preserved by him were obtained in this manner. However, most of these seem to have been labeled "raised from seed," and as no other record has been made of the occurrence of this species in Illinois it seems best to place it on the doubtful list at present. It has a narrow panicle and still smaller spikelets than *S. avenacea,* the glumes being 6 to 8 mm. long and the awn less than 1.5 inches long.

20. ARISTIDA L.

Triple-awned Grass. Needle Grass

These grasses were found in abundance on the original prairie, and many species are still found in Illinois. They usually grow in large tufts, or bunches, and are readily distinguished by the three-parted awn of the lemma. The glumes are long and narrow and sometimes awn-tipped. The one-flowered spikelets are borne in narrow panicles. Like Stipa, the lemmas have a sharp-pointed callus. The leaves are long and narrow, usually involute. The ligule is very short, never over 2 mm. in length, and is fringed with hairs. The species are of no value for grazing and often are very annoying to grazing animals because of the awns and the sharp-pointed callus which penetrate the skin. There are both annual and perennial species.

a. Awns jointed to the lemma, and of nearly equal length.
  b. Awns united into a conspicuous spiral column 6 mm. or more long. *A. tuberculosa*
  bb. Awns not united into a spiral column, reflexed and somewhat coiled at base. *A. desmantha*
aa. Awns not jointed to the lemma.
  b. Central awn much longer than the lateral awns, the lateral awns erect.
    c. Central awn forming a distinct spiral at base; second glume not awned.
      d. Glumes almost equal, awn-pointed, usually 7 to 9 mm. long; lateral awns erect, about 2 mm. long. *A. dichotoma*
      dd. Glumes unequal, pointed, the first about two-thirds as long as the second, which is 12 to 14 mm. long; lateral awns spreading, one-third to one-half the length of the central awn. *A. basiramea*
    cc. Central awn not forming a distinct spiral, rarely a loose one, the awn either horizontal or reflexed, glumes awned, unequal, the second glume equaling the lemma.
      d. Central awn always horizontal; lemma 5 to 7 mm. long. *A. gracilis*

dd. Central awn forming a loose spiral or strongly reflexed and hook-like; lemma 20 to 30 mm. long. *A. ramosissima*

bb. Central awn differing slightly in length from the lateral ones, the latter more or less horizontal; glumes almost equal in length.

c. Awns not over 3 cm. long, glumes 9 to 12 mm. long.

d. Leaf-blades smooth, not hairy; first glume longer than the second. *A. purpurascens*

dd. Leaf-blades with long hairs near the base; first glume usually equal to, but sometimes longer than the second. *A. stricta*

cc. Awns 4 to 7 cm. long; glumes 20 to 30 mm. long. *A. oligantha*

Aristida basiramea Engelm.

Forked Aristida. Tufted Triple-awn (Fig. 131)

Gleason '10, 148.

Culms branched, 8 to 24 inches tall; sheaths smooth, blades 1 to 6 inches long, 1 to 2 mm. wide; panicles usually less than 6 inches long, narrow, often partly included in the upper sheaths; glumes pointed, unequal, the first 8 to 12 mm., the second 12 to 14 mm.; lemma about 10 mm. long, the middle awn 1 to 2 cm. long, the lateral awns 2 to 7 mm.

This species is an annual growing in dry, sandy soil, and sandy barrens.

CHAMPAIGN CO. Urbana, *Waite,* Sept., 1888. JO DAVIESS CO. Without locality, *Pepoon.* HENDERSON CO. Oquawka, *Patterson* 232; Oquawka, *Tracy* in 1887. OGLE CO. Oregon, *Waite,* Sept., 1888. ROCK ISLAND CO. Barstow, *McDonald,* Aug., 1903; Osborn, *Seymour,* Sept., 1884. ST. CLAIR CO. Without locality, *Brendel* in 1850.

Aristida desmantha Trin. and Rupr.

Western Aristida (Fig. 126)

Culms branched, 1 to 2 feet tall; sheaths loose, smooth; blades 4 to 8 inches long, 1 to 2 mm. wide, roughened only on the upper surface; panicle 4 to 8 inches long, about half as wide, the branches ascending; glumes shiny brown, about equal, 15 to 20 mm. long; lemma shorter, the awns about equal, jointed to the lemma, reflexed and somewhat coiled at base but not forming a spiral column.

This species belongs to the southwestern part of the United States. It is found in dry soil.

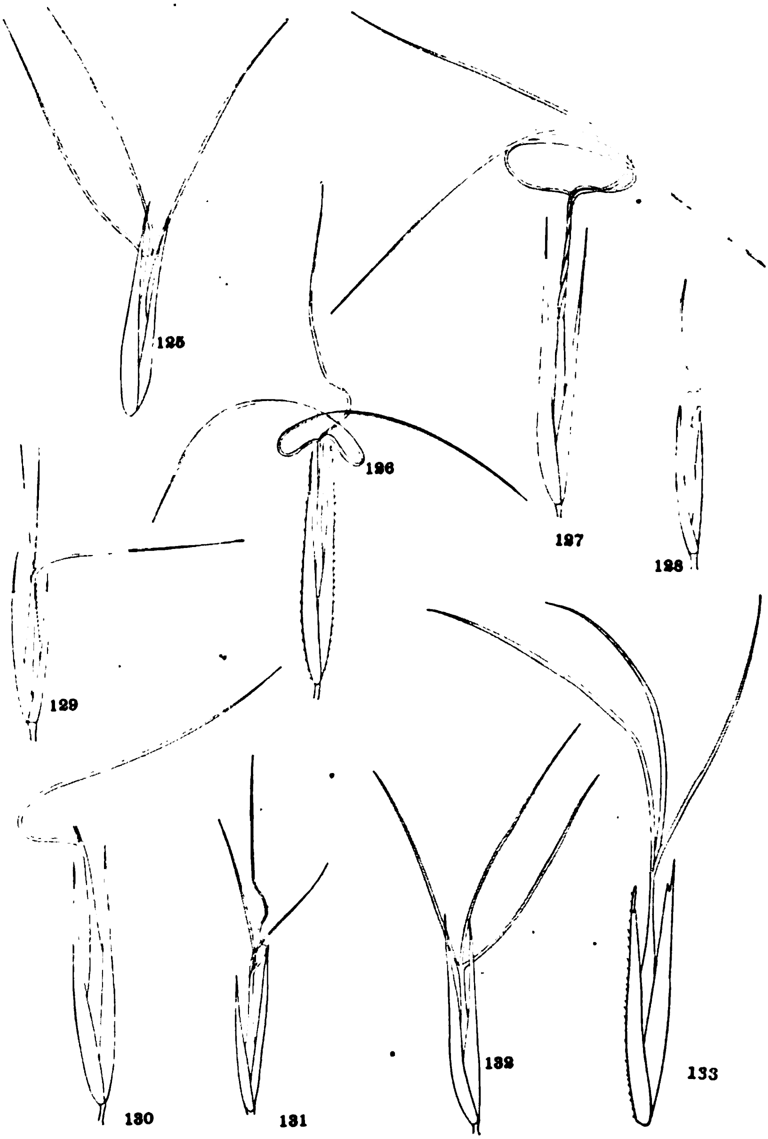
ILLINOIS SPECIMENS: Without locality, *Vasey.* MASON CO. Without locality, *M. S. Bebb* in 1861.

Aristida dichotoma Michx.

Poverty Grass (Fig. 128)

Lapham '57, 545, 569 (Plate 2, Fig. 2); Patterson '76, 50; Flagg '78, 280; Brendel '87, 88.

Culms slender, much branched, usually branching at every node, 4 to 24 inches tall; sheaths loose, smooth; blades 1 to 3 inches long, 1 to 2 mm. wide, involute; panicles spike-like, 2 to 6 inches long; glumes almost equal, 7 to 8 mm. long, sharp-pointed; lemma shorter,



Figs. 125–133.—Spikelets: 125, *A. stricta;* 126, *A. desmantha;* 127, *A. tuberculosa;* 128, *A. dichotoma;* 129, *A. gracilis;* 130, *A. ramossissima;* 131, *A. basiramea;* 132, *A. purpurascens;* 133, *A. oligantha*

the lateral awns much reduced, the middle awn 3 to 6 mm. long, finally coiled at the base.

These plants are found in dry, sandy or gravelly soil. They usually grow in quite large tufts.

ILLINOIS SPECIMENS: Without locality, *Hall* in 1861; southern Illinois, *Vasey*. JO DAVIESS CO. Without locality, *Pepoon*. HANCOCK CO. Augusta, *Mead* in 1842. MACOUPIN CO. Carlinville, *Robertson*, July, 1882. MENARD CO. Athens, *Hall* in 1861. PERRY CO. Du Quoin, *Vasey*. ST. CLAIR CO. Mascoutah, *Welsch*.

Aristida gracilis Ell.

Slender Aristida. Slender Beard Grass (Fig. 129)

Lapham '57, 545, 571; Patterson '76, 50; Flagg '78, 281; Brendel '87, 88.

Culms slender, branched at the base, 6 to 20 inches tall; sheaths smooth, blades 1 to 4 inches long, 1 to 2 mm. wide, usually drying involute; inflorescence a slender raceme or spike-like panicle, 2 to 6 inches long; glumes unequal, the second equaling the lemma, which is about 6 mm. long; lateral awns erect, 2 to 6 mm. long, median awn spreading, usually about 10 mm. long.

This species is seldom found in very large tufts; often the plants occur singly. They are found in dry, usually sandy soil.

ILLINOIS SPECIMENS: Without locality, southern Illinois, *Vasey*. FULTON CO. Without locality, *Brendel*. JO DAVIESS CO. Without locality, *Pepoon*. HENDERSON CO. Oquawka, *Patterson*. MACOUPIN CO. Carlinville, *Robertson*, Aug., 1880. MENARD CO. Athens, *Hall* in 1867. ST. CLAIR CO. Mascoutah, *Welsch*. UNION CO. Without locality, *French*, Sept., 1878; without locality, *Wolf*; Anna, *Seymour*, Aug., 1880. WABASH CO. Without locality, *Shearer*.

Aristida oligantha Michx.

Few-flowered Aristida (Fig. 133)

Michaux '03, 41; Lapham '57, 545, 571; Patterson '76, 50; Flagg '78, 281; Brendel '87, 88.

Culms much branched, 1 to 2 feet tall; sheaths loose, smooth; blades 1 to 6 inches long, 1 to 2 mm. wide, smooth, usually involute; inflorescence a raceme or spike-like panicle; glumes unequal and awned; lemmas 20 to 30 mm. long; awns nearly equal, 4 to 7 cm. long.

This species was first found on the prairies of Illinois by Michaux. It grows in dry soil, and was probably the commonest species of Aristida on the original prairies of the state.

ILLINOIS SPECIMENS: Without locality, *Mead*. CHAMPAIGN CO. Near Champaign, *Clinton*, Oct., 1898. CLINTON CO. Carlyle, *Mead*; Shattuck, *Waite*, Aug., 1897. COOK CO. Lyons, *Hill*, Aug., 1898. HANCOCK CO. Augusta, *Mead*. HENDERSON CO. Near Oquawka, *Patterson*, Sept., 1881. JACKSON CO. Without locality, *French*, Aug., 1905. MACOUPIN CO. Brighton, *McDonald*, Sept., 1894; Medora, *McDonald*; Carlinville, *Robertson*, Aug., 1882. MARION CO. Odin, *Vasey* in 1862. MENARD CO. Athens, *Hall*. PEORIA CO. Princeville, *V. H. Chase* 1248. ROCK ISLAND CO. Barstow, *McDonald*, Sept., 1904. ST. CLAIR CO. Mascoutah, *Welsch*. UNION CO. Cobden, *Seymour*, Aug., 1880; Anna, *Seymour*, Aug., 1880. WABASH CO. Without locality, *Shearer*. WASHINGTON CO. Irvington, *French*, Sept., 1872.

Aristida purpurascens Poir.

Purplish Aristida (Fig. 132)

***Aristida geyeriana*, Lapham '57, 545, 571. *Aristida purpurascens*, Lapham '57, 545, 571; Patterson '76, 50; Flagg '78, 281; Brendel '87, 88.**

Culms 1 to 2.5 feet tall, smooth, not much branched; sheaths smooth; blades 4 to 8 inches long, 1 to 2 mm. wide, smooth, sometimes flat but usually involute; panicle spike-like, purplish, 4 to 10 inches long; glumes unequal, pointed, 10 to 12 mm. long; awns 1.5 to 3 cm. long, the middle one slightly longer than the lateral.

This species is a perennial. It may usually be distinguished by its purplish infloresence. It usually grows in sandy or gravelly soil.

ILLINOIS SPECIMENS: Without locality, *M. S. Bebb.* LAKE CO. Beach, *Gates* 3260. MASON CO. Without locality, *Vasey.* MENARD CO. Athens, *Hall,* 1861. ST. CLAIR CO. Without locality, *Brendel* in 1850.

Aristida ramosissima Engelm.

Branched Aristida (Fig. 130)

Lapham '57, 545, 569; Patterson '76, 50; Flagg '78, 280; Brendel '87, 88.

Culms 6 to 24 inches tall, much branched, the branches spreading; sheaths loose, smooth; blades roughened above, usually involute, 1 to 3 inches long, 1 to 2 mm. wide; glumes unequal, 15 to 20 mm. long, lateral awns very small and erect, the central awn 15 to 20 mm. long with a semicircular or S-shaped bend at the base.

This species is found in dry soil. It is a middle western species.

ILLINOIS SPECIMENS: Without locality, *Beal* in 1862; without locality, *Vasey.* MARION CO. Odin, *Vasey.* MACOUPIN CO. Carlinville, *Robertson.* ST. CLAIR CO. Without locality, *Brendel;* Mascoutah, *Welsch.* UNION CO. Jonesboro, *Seymour,* Aug., 1880. WABASH CO. Without locality, *Schneck,* July, 1879; without locality, *Shearer;* Mt. Carmel, *Schneck,* Sept., 1877 and Aug., 1898; Lick Prairie, *Schneck,* Aug., 1878.

Aristida stricta Michx.

Erect Aristida (Fig. 125)

Engelmann '44, 103; Lapham '57, 545, 571; Patterson '76, 50; Flagg '78, 281; Brendel '87, 88.

Culms 2 to 4 feet tall; sheaths smooth; blades 8 to 12 inches long, densely pubescent, almost wooly on the upper surface near the base, usually involute; panicle spike-like, 6 to 24 inches long; glumes about equal or the first longer than the second, awn-pointed; lateral awns usually shorter than the central one, which is 1 to 2 cm. long.

This species is found in dry soil. It is a southern species closely resembling *A. purpurascens,* but is taller and lacks the purplish color.

MASON CO. Without locality, *Mead,* Aug., 1845.

Aristida tuberculosa Nutt.

Sea-beach Aristida (Fig. 127)

Aristida tuberculata, Lapham '57, 545, 571. *A. tuberculosa*, Patterson '76, 50; Flagg '78, 281; Higley and Raddin '91, 141; Huett '97, 129; McDonald '00, 103; Gleason '07, 182; Gleason '10, 148.

Culms 6 to 20 inches tall, branched at the base, somewhat swollen at the nodes; sheaths loose, smooth; blades 5 to 10 inches long, about 2 mm. wide, rough above; panicle open; glumes 2.5 cm. long, with pointed tips; awns jointed to the lemma and twisted at base into a slender column nearly as long as the lemma.

This species is most commonly found along the southern part of the Atlantic coast. It is also found along the Great Lakes and in the interior wherever there are sandy areas.

ILLINOIS SPECIMENS: Without locality, *Mead*. COOK CO. Chicago, *Babcock*, July, 1870. JO DAVIESS CO. Without locality, *Pepoon*. HENDERSON CO. Oquawka, *Patterson*, Sept., 1872. LEE CO. Dixon, *Seymour*, Sept., 1882. MASON CO. Without locality, *M. S. Bebb* in 1861; without locality, *Hall* in 1861 and Sept., 1876. UNION CO. Cobden, *Waite*, Sept., 1884.

21. **MUHLENBERGIA** Schreb.

This genus has one-flowered spikelets which in Illinois species are, with one exception, borne in very narrow panicles. The glumes are thin and usually sharp-pointed or awned. The lemma is also pointed or awned and incloses the grain, thus differing from the nearly related genus Sporobolus, in which the grain is free. The awns are variable even in the same individual and do not afford good characters for the separation of species. There is a short, usually hairy callus at the base of the lemma. Many of the species have long, scaly rootstocks. All Illinois species are perennial. The leaves are mostly long and narrow and the ligule is short and membranous.

The species of Muhlenbergia are of little economic importance. It is said that the species which inhabit damp ground are useful for hay if cut before the stems become hard, but most of the species grow in waste places and are usually looked upon as weeds. The long rootstocks make them somewhat difficult to destroy; thoro cultivation is the only method of eradication recommended. *M. mexicana, foliosa,* and *racemosa* are the only species likely to cause trouble in this state.

a. Glumes minute, always less than one-fourth the length of the spikelet, the first glume often wanting. *M. schreberi*
aa. Glumes always more than one-fourth the length of the spikelet.
  b. Plants never from long, scaly rootstocks; leaves elongate and very narrow, usually involute.
    c. Panicle open, with long, spreading branches; spikelets on long, capillary pedicels; glumes about one-half the length of the lemma. *M. capillaris*
    cc. Panicle narrow and spike-like; spikelets nearly sessile; glumes nearly as long as the lemma, at least two-thirds its length. *M. cuspidata*
  bb. Plants always from long, scaly rootstocks; leaves not elongate, seldom becoming involute.

- c. Glumes awned, always considerably longer than the lemma, sometimes nearly twice its length; panicle usually compact, resembling an interrupted spike. *M. racemosa*
- cc. Glumes seldom awned, usually not longer than the lemma, but sometimes slightly longer; panicles usually slender.
  - d. Glumes always shorter than the lemma, never more than three-fourths its length, broad at base; leaf-blades spreading.
    - e. Lemma awnless or short-awned; spikelets 1.5 to 2 mm. long; nodes not pubescent; culms not densely short pubescent. *M. sobolifera*
    - ee. Lemma long-awned; spikelets 3 to 4 mm. long; nodes pubescent; culms densely short pubescent. *M. tenuiflora*
  - dd. Glumes about equal in length to the lemma, sometimes longer, very narrow at the base; leaf-blades erect, or nearly so.
    - e. Culms smooth and shiny below the nodes, never covered with fine hairs. *M. mexicana*
    - ee. Culms with very short, fine hairs for an inch or two below the nodes.
      - f. Callus without hairs. *M. glabriflora*
      - ff. Callus with hairs one-third to one-half the length of the lemma.
        - g. Panicles few-flowered; lemma usually long-awned. *M. umbrosa*
        - gg. Panicles densely flowered; lemma not awned. *M. foliosa*

Muhlenbergia capillaris (Lam.) Trin.

Long-awned Hair Grass (Fig. 136)

Culms growing in tufts, 1.5 to 3 feet tall, usually smooth; sheaths smooth, short at the base of the plant, and often overlapping, but longer near the summit; blades 4 to 12 inches long, about 2 mm. wide, usually involute; panicle spreading, with long, capillary branches, spikelets, excluding the awn, 3.5 to 4 mm. long, on long, capillary pedicels, which are thickened near the base of the spikelet; glumes about half as long as the awned lemma; awn 5 to 18 mm. long; callus hairs very short.

This species is found in dry soil. So far only one specimen has been seen from Illinois. The panicle is usually purple.

UNION CO. Without locality, *Seymour* in 1881.

Muhlenbergia cuspidata (Torr.) Rydb.

(Fig. 137)

Culms in tufts, 1 to 2 feet tall, very slender, smooth; sheaths and blades smooth; blades 4 to 10 inches long, very narrow, usually involute; panicle very slender, few-flowered; spikelets 3 to 4 mm. long, the glumes with a cusp or short awn about two-thirds as long as the lemma; callus hairs wanting.

This species is described in Gray's Manual (seventh edition) as *Sporobolus brevifolius* (Nutt.) Scribn. It is found in dry places. The only Illinois specimens seen were collected on dry, gravelly hills, or on limestone rocks on a river bank.

WILL CO. Joliet, *Hill* 185 in 1906; bank of Du Page river, Bird's Bridge, *Hill* 36 in 1912.

Muhlenbergia foliosa Trin.

(Fig. 138)

Culms 2 to 3 feet long, often bent near the base and lying on the ground, branched above the base, the branches erect, one or two inches of surface below the nodes covered with very fine, short hairs; sheaths smooth; blades rough to the touch, 1.5 to 6 inches long, 2 to 5 mm. wide; panicles well beyond the uppermost sheath, usually rather thick, campactly flowered; spikelets 2.5 to 3 mm. long, the glumes nearly or quite equal to the lemma; callus covered with soft hairs nearly half as long as the spikelet.

This species closely resembles *M. mexicana* in general appearance and habit. *M. foliosa* can be readily distinguished by the minute hairs on the culm just below the nodes. The panicles vary greatly in width. The narrower panicles resemble those of *M. umbrosa,* which has long-awned lemmas. There is an awned form of *M. foliosa,* but no specimens of it were found among the Illinois collections. The plants are usually found in damp meadows and swamps. Most of the herbarium specimens were labeled *M. mexicana filiformis.*

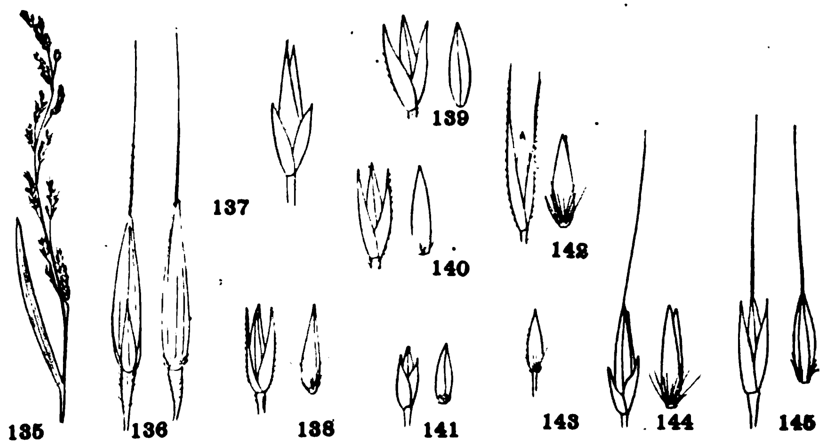
ILLINOIS SPECIMENS: Without locality, *Ball.* CHAMPAIGN CO. Without locality, *Burrill,* Oct., 1877; Champaign, *Clinton,* Oct., 1895. FULTON CO. Without locality, *Wolf* in 1881. JO DAVIESS CO. Bluffs of Apple river, *Pepoon* 611. KANKAKEE CO. Waldron, *Hill,* Sept., 1873. MCHENRY CO. Algonquin, *Nason,* Aug., 1879. PEORIA CO. Peoria, *Brendel.* PIATT CO. White Heath, *Mosher,* Oct., 1914. STARK CO. Wady Petra, *V. H. Chase* 1268. WILL CO. Joliet, *Skeels,* Sept., 1904. WINNEBAGO CO. Fountaindale, *M. S. Bebb.*

Muhlenbergia glabriflora Scribn.

(Fig. 139)

This species is very much like *M. foliosa* in general appearance. The culms are simple for nearly half their length, then branch profusely and bear numerous panicles, often partially included in the upper sheaths, more typically cylindrical than in *M. foliosa.* The spikelets are of about the same size, but the callus bears no hairs, making it very easy to distinguish the species. The leaf blades are generally shorter than in *M. foliosa.* The plants are found in woods and other shady places.

ILLINOIS SPECIMENS: Without locality, *Wolf.* CHRISTIAN CO. Taylorville, *Andrews,* Sept., 1898. MENARD CO. Athens, *Hall* in 1868. ST. CLAIR CO. Mascoutah, *Welsch.* WABASH CO. Without locality, *Shearer,* Aug., 1898 and 1899.



Figs. 135–145.—135, *M. mexicana,* inflorescence; 136, *M. capillaris,* spikelet; 137, *M. cuspidata,* spikelet; 138, *M. foliosa,* spikelet; 139, *M. glabriflora,* spikelet; 140, *M. mexicana,* spikelet; 141, *M. sobolifera,* spikelet; 142, *M. racemosa;* 143, *M. schreberi,* spikelet; 144, *M. tenuiflora,* spikelet; 145, *M. umbrosa,* spikelet

Muhlenbergia mexicana (L.) Trin.

Meadow Muhlenbergia. Mexican Drop-seed (Figs. 135 and 140)

Agrostis lateriflora, Michaux '03, 53. *Muhlenbergia mexicana,* Lapham '57, 545, 566; Babcock '73, 97; Patterson '76, 49; Flagg '78, 280; Brendel '87, 63; Higley and Raddin '91, 141; Huett '97, 129.

Culms 2 to 4 feet long, often branching at the base, lying on the ground and rooting at the lower nodes, the remainder erect, always smooth; blades rough to the touch, 2 to 6 inches long, 2 to 6 mm. wide; panicles numerous, usually narrowed toward the tip, often partially inclosed in the upper sheath; spikelets 2.5 to 3 mm. long; glumes awn-pointed or with a short awn, about as long as the lemma.

This species is common in fields, gardens, and in waste places. It is a troublesome weed in some places. It is recommended that the areas containing this weed be thoroly cultivated and the rootstocks exposed to the sun.

ILLINOIS SPECIMENS: Without locality, *Brendel* in 1873; without locality, *Mead;* without locality, *Vasey.* CHAMPAIGN CO. Urbana, *Gates,* Oct., 1907; Urbana, *Gibbs,* Sept., 1898; Champaign, *Mosher,* Sept., 1914; Urbana, *Mosher,* Sept., 1914. COOK CO. Wolf lake, *Hill,* Sept., 1892. FULTON CO. Without locality, *Pepoon;* Canton, *Wolf.* JO DAVIESS CO. Bluffs of Apple river, *Pepoon.* KANKAKEE CO. Kankakee, *Crampton,* Sept., 1913. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* Sept., 1900. ST. CLAIR CO. Mascoutah, *Welsch.* SANGAMON CO. Springfield, *M. S. Bebb* in 1861. STARK CO. Wady Petra, *V. H. Chase,* Aug., 1893. WILL CO. Joliet, *Skeels,* Sept., 1904. WABASH CO. Without locality, *Schneck,* Sept., 1880; Mt. Carmel, *Schneck,* Sept., 1897.

Muhlenbergia racemosa (Michx.) B. S. P.

Marsh Muhlenbergia. Wild Timothy (Fig. 142)

Agrostis racemosa, Michaux '03, 53. ***Muhlenbergia glomerata***, Lapham '57, 545, 566; Babcock '73, 97; Patterson '76, 49; Flagg '78, 280; Patterson '87, 63; Higley and Raddin '91, 141.

Culms smooth, often much branched, 1 to 3 feet tall, erect, with fine short pubescence below the nodes; sheaths smooth, blades usually rough to the touch, 2 to 5 inches long, 2 to 6 mm. wide; panicles dense and spike-like; spikelets 4 to 6 mm. long, the glumes always awned and considerably longer than the lemma, sometimes almost twice as long.

This species is found in wet places, such as swamps and bogs.

CHAMPAIGN CO. Champaign, *Clinton*, Oct., 1895. HANCOCK CO. Augusta, *Mead*. HENDERSON CO. Oquawka, *Patterson*, Sept., 1872. KANE CO. Elgin, *Sherff* 1946. LAKE CO. Cedar lake, Lake Villa, *Gleason* and *Shobe* 128; Sun lake, Lake Villa, *Gleason* and *Shobe* 200. MCHENRY CO. Ringwood, *Vasey*. MADISON CO. East Alton, *McDonald*, Sept., 1900. MENARD CO. Athens, *Hall* in 1866. OGLE CO. Oregon, *Waite*, Sept., 1885. PEORIA CO. Peoria, *Brendel;* Princeville, *V. H. Chase* 940. STARK CO. Wady Petra, *V. H. Chase* 1943. WINNEBAGO CO. Fountaindale, *M. S. Bebb* in 1873.

Muhlenbergia schreberi J. F. Gmel.

Dropseed. Nimble Will (Fig. 143)

Dilepyrum minutiflorum, Michaux '03, 40. ***Muhlenbergia diffusa***, Lapham '57, 545, 567; Patterson '76, 49; Flagg '78, 280; Brendel '87, 63; Huett '97, 129. ***Muhlenbergia schreberi***, Gleason '12, 41.

Culm smooth, much branched, the basal part usually lying on the ground and often rooting at the nodes, the ends erect; sheaths loose, smooth; blades rough, 1.5 to 3.5 inches long, 1 to 4 mm. wide; panicles numerous, slender, densely flowered; spikelets, excluding the awn about 2 mm. long, the first glume nearly obsolete, the second very small, the lemma awned.

This species grows in dry places.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Urbana, *Gibbs;* Urbana, *Clinton*, Oct., 1895; Champaign, *Percival*, Oct., 1876; Urbana, *Gates*, Sept., 1907. COOK CO. Evanston, *Shipman*, Sept., 1875; Chicago Heights, *A. Chase*, Sept., 1897; Palos Park, *Umbach*, Sept., 1909. DU PAGE CO. Hinsdale, *Smith*, Sept., 1902; Naperville, *Umbach*, Sept., 1898. FULTON CO. Without locality, *Pepoon;* Canton, *Wolf*. JO DAVIESS CO. Without locality, *Pepoon*. HENDERSON CO. Oquawka, *Patterson*, Sept., 1873. LAKE CO. River Forest, *Hill*, Aug., 1890. MACOUPIN CO. Carlinville, *Robertson*, Aug., 1882. OGLE CO. Oregon, *Waite*, Aug., 1884. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald*, Sept., 1900. RANDOLPH CO. Bremen, *Hill*, Aug., 1892. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase* 1270, 1165, 1277. WABASH CO. Without locality, *Schneck*, July, 1900; without locality, *Shearer;* Mt. Carmel, *Schneck*, Sept., 1904. WILL CO. Mokena, *Chase;* Joliet, *Skeels*, Sept., 1904.

Muhlenbergia sobolifera (Muhl.) Trin.

Rock Muhlenbergia (Fig. 141)

Lapham '57, 545, 566; Patterson '76, 49; Flagg '78, 280; Brendel '87, 63; Higley and Raddin '91, 141.

Culms smooth, erect or nearly so, 1 to 3 feet tall; sheaths smooth; blades rough, shorter on the culm, 1 to 6 inches long, 2 to 6 mm. wide; panicles long and very slender; spikelets 1.5 to 2.5 mm. long, the glumes sharp-pointed and one-half to two-thirds as long as the lemma.

This species is usually found in rocky woods.

FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon.* MACOUPIN CO. Carlinville, *Robertson,* Aug., 1882. MENARD CO. Athens, *Hall* in 1869. PEORIA CO. Peoria, *Brendel.* WABASH CO. Without locality, *Schneck,* Oct., 1881; Mt. Carmel, *Schneck,* Sept., 1897.

Muhlenbergia tenuiflora (Willd.) B. S. P.

Slender Muhlenbergia (Fig. 144)

***Muhlenbergia willdenowii,* Lapham '57, 545, 566 (Plate 1, Fig. 9); Babcock '73, 97; Patterson '76, 49; Flagg '78, 280; Brendel '87, 63; Higley and Raddin '91, 141.**

Culms simple or very sparingly branched, covered with fine, short hairs which point downwards; nodes pubescent; sheaths generally with a few very fine hairs at least near the edges, usually shorter than the internodes; blades rough, 2.5 to 8 inches long, 2 to 8 mm. wide; panicles long and slender but rather densely flowered; spikelets 3 to 4 mm. long, glumes unequal, one-half to two-thirds the length of the lemma, which bears an awn 2 to 4 times the length of the body.

This species has the broadest leaves of any of the genus found in Illinois. They are usually horizontally spreading. It resembles *M. sobolifera* more than any other species, but the larger spikelets and hairy culms easily distinguish it. The plants grow in rocky woods and other shady places.

CHAMPAIGN CO. Urbana, *Seymour* and *Waite,* July, 1886. COOK CO. Palos Park, *Umbach,* Aug., 1909. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon.* KANE CO. Elgin, *Vasey.* KANKAKEE CO. Kankakee, *De Selm,* Sept., 1913. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* Sept., 1902; Glasford, *Wilcox,* Aug., 1902. WABASH CO. Mt. Carmel, *Schneck* in 1879; Hanging Rock, *Schneck,* Sept., 1904.

Muhlenbergia umbrosa Scribn.

Wood Muhlenbergia (Fig. 145)

***Muhlenbergia sylvatica,* Lapham '57, 545, 566; Babcock '73, 97; Patterson '76, 49; Flagg '78, 280; Brendel '87, 63; Higley and Raddin '91, 141; Huett '97, 129.**

Culms usually much branched, 1 to 3 feet tall, with very fine, short hairs below the nodes; sheaths smooth; blades rough, 2 to 7 inches long, 2 to 6 mm. wide; panicles long and very narrow, few-flowered; spikelets, excluding the awn, 2.5 to 3 mm. long, glumes awn-pointed

or slightly awned, shorter than the lemma, which bears an awn usually 6 to 12 mm. long.

This species is found in moist woods. It is much like *M. foliosa* and *M. glabriflora* in general appearance, but may be distinguished by the slender, few-flowered panicle and by a long-awned lemma. In rare instances a short-awned form was found among Illinois specimens.

ILLINOIS SPECIMENS: Without locality, *Wolf* in 1882. CARROLL CO. Mt. Carroll, *Shimer*, Oct., 1891. DU PAGE CO. Wheaton, *Moffatt*, Sept., 1892. FULTON CO. Canton, *Wolf*. KANKAKEE CO. Kankakee, *De Selm*, Sept., and Oct., 1913. MENARD CO. Without locality, *Hall;* Athens, *Hall* in 1874. PEORIA CO. Peoria, *Brendel;* Princeville, *V. H. Chase*, Oct., 1900. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Near Wady Petra, *V. H. Chase*, Sept., 1906. WABASH CO. Without locality, *Shearer;* Hanging Rock, *Schneck*, Sept., 1900.

22. BRACHYELYTRUM Beauv.

This genus includes a single species in which the plants are perennial from short rootstocks. The culms are tall and slender and the blades rather short and broad. The ligules are membranous, from 1 to 2 mm. long, the margin irregular. The inflorescence is a very narrow, few-flowered panicle. The spikelets are one-flowered, the glumes very minute or obsolete, and the lemma is awned.

Brachyelytrum erectum (Schreb.) Beauv.

Bearded Short Husk (Figs. 146 and 147)

Brachyelytrum aristatum, Lapham '57, 545, 567 (Plate 1, Fig. 10); Patterson '76, 49; Flagg '78, 280; Brendel '87, 63; Higley and Raddin '91, 142.

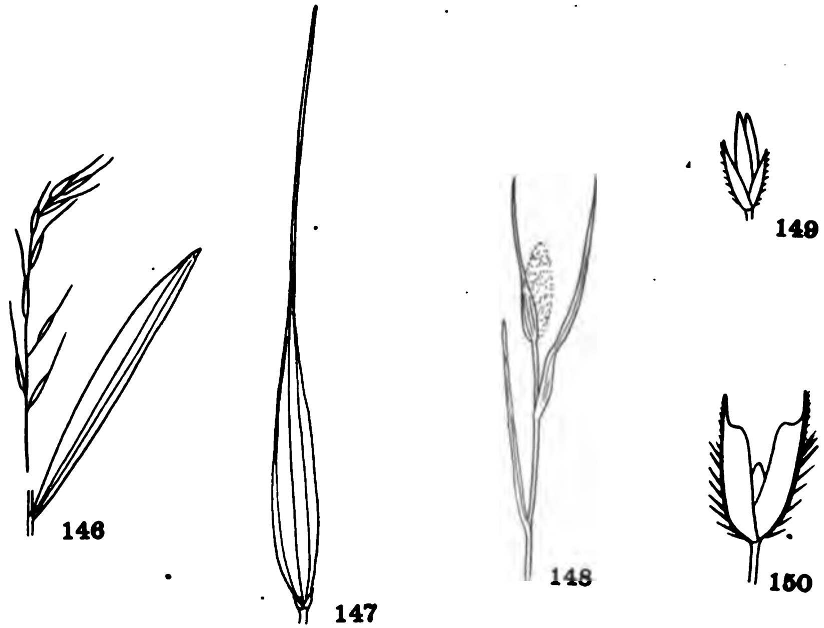
Culms erect, unbranched, densely pubescent at and near the nodes; sheaths with a few hairs, shorter than the internodes; blades 3 to 5 inches long, 6 to 18 mm. wide, rough to the touch; spikelets, excluding the awns, 10 mm. long, rough, and slightly pubescent.

This grass is found in shady places, usually in damp, rocky woods.

ILLINOIS SPECIMENS: Without locality, *Mead;* without locality, *Vasey;* southern Illinois, *Brendel*. CHAMPAIGN CO. Urbana, *Butts* and *Seymour*, June, 1880. COOK CO. Palos Park, *Umbach*, Aug., 1909; Glencoe, *Johnson*, Sept., 1890. FULTON CO. Canton, *Wolf*. JO DAVIESS CO. Along Apple river, *Pepoon* 691. HENDERSON CO. Oquawka, *Patterson*, Aug., 1872. LA SALLE CO. Near Starved Rock, *A. Chase*, July, 1901; Starved Rock, *Hill* 138 in 1901. PEORIA CO. Glasford, *Wilcox*, July, 1902; Peoria, *Brendel;* Springdale, Peoria, *McDonald*, July, 1890. POPE CO. Herod, *Clinton*, July, 1898. ST. CLAIR CO. Mascoutah, *Welsch*. VERMILION CO. Danville, *Waite*, June, 1886. WABASH CO. Without locality, *Schneck*, July, 1905; Mt. Carmel, *Schneck*, Sept., 1886; Hanging Rock, *Schneck*, Sept., 1904 and Aug., 1879.

23. HELEOCHLOA Host

This grass, which has been sparingly introduced into this country, is a native of Europe and Asia. It grows in small bunches. The spike-like panicles have the general appearance of *Phleum pratense*, our common timothy or herd's grass. The panicles are partially included in the enlarged upper sheaths. The spikelets are one-flowered, the glumes, lemma, and palea are all of the same texture. The glumes are flattened and keeled, with a row of stout hairs along the keel. The blades are short and narrow; the ligule is composed of a ring of short hairs.



Figs. 146–150.—146, *B. erectum,* inflorescence; 147, *B. erectum,* spikelet; 148, *H. schoenoides,* inflorescence; 149, *H. schoenoides,* spikelet; 150, *P. pratense,* spikelet

Heleochloa schoenoides (L.) Host

Rush Cat-tail Grass (Figs. 148 and 149)

Culms smooth, 4 to 18 inches tall, sheaths much shorter than the internodes, the upper sheaths enlarged; blades 1 to 3 inches long, sharp-pointed, rather rough on the upper surface; panicle 1 to 1.5 inches long; spikelets about 2.5 mm. long.

This grass has not been reported from many localities in Illinois. It is found in waste places.

COOK CO. Blue Island, *Robert Bebb,* Aug., 1902 and 1903; Chicago, *Somes,* Aug., 1909. ST. CLAIR CO. East St. Louis, *Eggert,* Aug., 1893.

24. PHLEUM L.

Cat-tail Grass

The native species of this genus (*P. alpinum*) does not occur in Illinois, being found only on high mountains or in the arctic regions of the continent. The introduced species, *P. pratense,* is cultivated everywhere in the state for hay. It is a perennial grass, growing in tufts, with long, cylindrical, spike-like panicles. The spikelets are one-flowered, flattened, and closely crowded. The lemma is thinner than the glumes and transparent. The leaves are long and flat, the ligules membranous, from 2 to 3 mm. long.

Phleum pratense L.

Timothy. Herd's Grass (Fig. 150)

Culms 1.5 to 3.5 feet tall, erect, smooth, enlarged, and bulbous at base; sheaths smooth; blades 3 to 12 inches long, 4 to 6 mm. wide; spikelets 2 to 5 mm. long, usually 3 mm.; glumes keeled and about twice as long as the lemma, the midnerve produced into a short awn 1 to 2 mm. long.

This species grows in meadows all over the state.

25. ALOPECURUS L.

Foxtail Grass

This genus includes plants with the inflorescence in spike-like panicles which somewhat resemble timothy, or herd's grass, *Phleum pratense.* The spikelets are one-flowered, flattened, with keeled glumes. The lemma is thin and transparent and bears an awn near the base. There are two species commonly found in Illinois. A third species, *A pratensis,* is mentioned by Lapham, Patterson, Flagg, and Huett as having been cultivated in Illinois. No Illinois specimens have been seen, however, except from the University experimental plots. It is included in the key, so that if any specimens are found, they may be identified.

Spikelets 4 to 6 mm. in length. *A. pratensis*
Spikelets never more than 3 mm. in length.
  Awn scarcely exceeding the spikelet and not extending over 1 mm. beyond it; spikelets 2.5 to 3 mm. long. *A. aristulatus*
  Awn exceeding the spikelet by the length of the glume or more; spikelets 2 mm. long. *A. geniculatus*

Alopecurus aristulatus Michx.

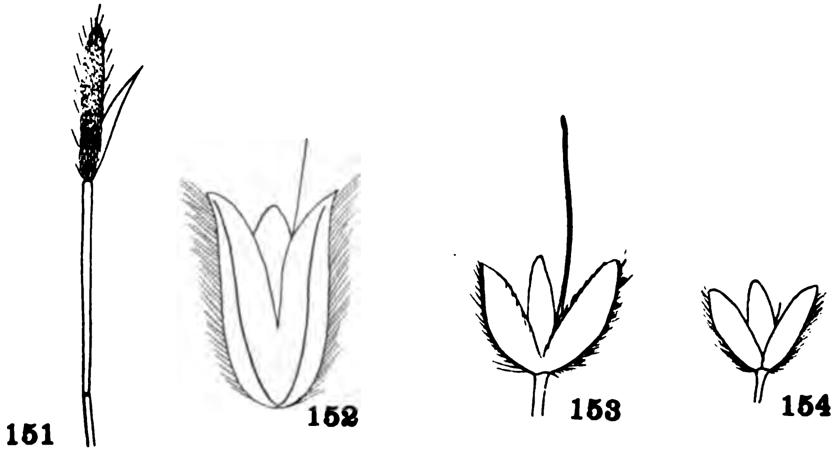
Wild Water Foxtail. Floating Foxtail (Fig. 154)

Alopecurus aristulatus, Lapham '57, 544, 562 (Plate 1, Fig. 3); Flagg '78, 280. *Alopecurus geniculatus* var. *aristulatus,* Brendel '87, 63; Higley and Raddin '91, 142; Huett '97, 129.

Culms slender, smooth, 6 inches to 2 feet tall, usually erect; sheaths smooth; blades roughened, 1 to 6 inches long, 1 to 4 mm. wide; spikelets about 2 mm. long, the awn very short, not extending beyond the panicle.

This species is described by earlier writers as being native to Illinois, and there seems to be no doubt on this point. It grows in the water along the edges of ponds and streams or in very wet soil.

ILLINOIS SPECIMENS: Without locality, *Vasey;* lakes in Illinois, *Eggert,* July, 1878. COOK CO. Winnetka, *Johnson,* May, 1889; Engelwood, *Umbach,* July, 1898. DU PAGE CO. Glen Ellyn, *Moffatt,* May, 1894. FULTON CO. Canton, *Wolf.* LAKE CO. Gilmer, *Gates,* July, 1907. MCHENRY CO. Without locality, *Brendel.* MENARD CO. Athens, *Hall,* June, 1865. PEORIA CO. Peoria, *Brendel.* ST. CLAIR CO. Without locality, *Brendel;* Mascoutah, *Welsch.*



Figs. 151–154.—151, *A. geniculatus,* inflorescence; 152, *A. pratensis,* spikelet; 153, *A. geniculatus,* spikelet; 154, *A. aristulatus,* spikelet

Alopecurus geniculatus L.

Marsh Foxtail (Figs. 151 and 153)

Lapham '57, 544, 562; Patterson '76, 49; Flagg '78, 280; Sherff '13, 594.

Culms 6 inches to 2 feet tall, slender, smooth, the base usually lying along the ground, the ends erect; sheaths smooth; blades roughened, 1 to 6 inches long, 1 to 4 mm. wide; panicles with a somewhat furry appearance due to the slender awns; spikelets 2.5 to 3 mm. long, the awn slightly bent, usually about twice the length of the spikelet.

This species was introduced from Europe. It is found in wet soil, especially in marshes and along the banks of ponds and streams.

COOK CO. Englewood, *Umbach,* July, 1898. DU PAGE CO. Glen Ellyn, *Hill,* May, 1894. EFFINGHAM CO. Edgewood, *Holden,* May, 1898. HENDERSON CO. Oquawka, *Patterson.* LAKE CO. Lake Forest, *Jensen,* May, 1895; Lake Zurich, *Hill,* June, 1899. MACOUPIN CO. Carlinville, *Robertson,* May, 1884. MCLEAN CO. Bloomington, *Burrill,* May, 1894. MARION CO. Without locality, *Lapham;* Salem, *M. S. Bebb* in 1860; Salem, *Hall.* MENARD CO. Athens, *Hall* in 1861. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* June, 1890. PULASKI CO. Beechwood, *Spencer,* May, 1900. ST. CLAIR CO. East St. Louis, *Eggert,* June, 1887; Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase* 471.

26. SPOROBOLUS R. Br.

Dropseed. Rush Grass

The species of this genus found in Illinois are all native to the state and include both annuals and perennials. They all grow in dry soil and nearly all have narrow, involute, pointed leaves. The ligules are membranous, from 1 to 3 mm. long. The spikelets are one-flowered and the fruit is not inclosed by the lemma, but is free and usually falls out as soon as ripe.

- a. Panicle diffuse, branches capillary. *S. asperifolius*
- aa. Panicle not diffuse, branches slender but not capillary.
  - b. Glumes very unequal; panicle branches ascending or spreading, panicle not spike-like (except secondary panicles in autumn).
    - c. Sheaths not bearded at the summit; spikelets 4 to 6 mm. long. *S. heterolepis*
    - cc. Sheaths conspicuously bearded at the summit; spikelets 2.5 to 3 mm. long. *S. cryptandrus*
  - bb. Glumes nearly equal; panicle contracted, more or less spike-like.
    - c. Sheaths much enlarged and always inclosing the lateral panicles, sometimes the terminal ones; blades short, scarcely longer than the sheaths.
      - d. Spikelets 2.5 to 3 mm. long; lemma not pubescent. *S. neglectus*
      - dd. Spikelets 3.5 to 4 mm. long; lemma pubescent. *S. vaginaeflorus*
    - cc. Sheaths never enlarged, except the upper which often partially incloses the panicle; blades long, very much longer than the sheaths, always very narrow and involute; plants perennial.
      - d. Spikelets 5 mm. or more long; panicles densely flowered and usually included in the enlarged upper sheaths.
        - e. Lemma and palea pubescent at the base.
          - f. Palea with a long sharp point; lemma about two-thirds the length of the palea. *S. clandestinus*
          - ff. Palea acute but not with a long sharp point, and only slightly longer than the lemma. *S. canovirens*
        - ee. Lemma and palea never pubescent at base, but always smooth and polished. *S. asper*
      - dd. Spikelets never more than 4 mm. long; panicles loosely flowered and not included in the upper sheath. *S. drummondii*

Sporobolus asper (Michx.) Kunth

Long-leaved Rush Grass (Fig. 155)

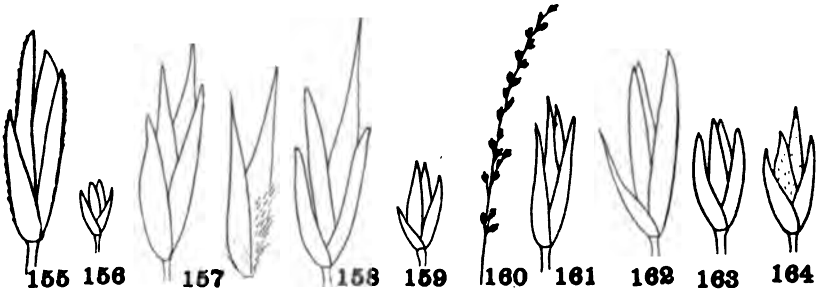
Sporobolus longifolius, Britton '07, 105.

Culms 1.5 to 4 feet tall, smooth; sheaths smooth; blades 4 to 18 inches long, 2 to 4 mm. wide, flat at base but soon becoming involute, smooth on the under surface, rough on the upper, and with long hairs near the base; panicle partially included in the upper sheath, 3 to 9 inches long, about half an inch wide; spikelets 5 to 6 mm. long.

This species is found in dry, usually sandy soil. *S. drummondii* closely resembles this species, but it has smaller spikelets, narrower and less dense panicles which are usually not inclosed in the sheath.

ILLINOIS SPECIMENS: Without locality, *Wolf* in 1882. CHAMPAIGN CO. Without locality, *Seymour*, Oct., 1880; St. Joseph, *Clinton*, Oct., 1895; Champaign, *Clinton*, Oct., 1895; Urbana, *Gates*, Oct., 1907. COOK CO. Chicago, *Umbach*, Sept.,

1898. HENDERSON CO. Oquawka, *Patterson.* MACOUPIN CO. Carlinville, *Robertson,* Sept., 1882. MENARD CO. Without locality, *Hall* in 1861. PEORIA CO. Peoria, *McDonald,* Sept., 1900 and 1901; Peoria, *Brendel;* Princeville, *V. H. Chase* 1180. ST. CLAIR CO. Without locality, *Brendel;* Mascoutah, *Welsch.* STARK CO. *V. H. Chase* 820. WABASH CO. Hanging Rock, *Schneck,* Sept., 1878. WILL CO. Joliet, *Skeels,* Sept., 1904.



Figs. 155–164.—155, *S. asper,* spikelet; 156, *S. asperifolius,* spikelet; 157, *S. canovirens,* spikelet; 158, *S. clandestinus,* spikelet; 159, *S. cryptandrus,* spikelet; 160, *S. drummondii,* inflorescence; 161, *S. drummondii,* spikelet; 162, *S. heterolepis,* spikelet; 163, *S. neglectus,* spikelet; 164, *S. vaginaeflorus,* spikelet

Sporobolus asperifolius (Nees & Meyen) Thurb.

Rough-leaved Dropseed (Fig. 156)

Culms 6 to 18 inches tall, smooth, erect from a long rootstock; sheaths short, smooth; blades flat, short, and pointed, very numerous near the base of the plant, 1 to 3 inches long, 2 to 3 mm. wide, very rough on the upper surface, smooth beneath; panicle spreading, 3 to 7 inches long and about half as wide, the spikelets 1.5 mm. long, on long, capillary pedicels, rarely 2- or 3-flowered.

This is a western species and has been reported only once from Illinois. It is found in dry soil.

KANE CO. Elgin, along railway track, *Sherff,* Aug., 1912.

Sporobolus canovirens Nash

(Fig. 157)

Culms 1 to 3 feet tall, smooth; sheaths smooth; blades narrow and involute except at base, 4 to 18 inches long, 2 to 4 mm. wide, with long hairs at the base; panicle 2 to 4 inches long, less than half an inch wide, partially included in the upper sheath; spikelets about 6 mm. long, lemma and palea slightly pubescent at base.

This species is found in sandy soil. In general appearance it resembles both *S. clandestinus* and *S. asper.*

ILLINOIS SPECIMENS: Without locality, *Wolf* in 1882. FULTON CO. Canton, *Wolf.* HENDERSON CO. Oquawka, *Patterson.*

Sporobolus clandestinus (Spreng.) Hitchc.

Rough Rush Grass (Fig. 158)

***Agrostis aspera*, Michaux '03, 52. *Vilfa aspera*, Lapham '57, 544, 563; Patterson '76, 49; Flagg '78, 280; Brendel '87, 63. *Sporobolus asper*, Huett '97, 129; McDonald '00, 103.**

Culms 2 to 5 feet tall, smooth; sheaths smooth; blades long, narrow, involute except at the base, 3 to 15 inches long, 2 to 4 mm. wide; panicle 2 to 6 inches long, 2 to 4 mm. wide; spikelets 6 to 8 mm. long, the lemma pubescent near the base.

This species is found in dry and sandy soil. It is distinguished by the exceedingly long, pointed palea.

COOK CO. Leydon, *Gates*. PEORIA CO. Peoria, *McDonald*, Sept., 1900 and 1901.

Sporobolus cryptandrus (Torr.) Gray

Sand Dropseed (Fig. 159)

Lapham '57, 545, 564; Patterson '76, 49; Flagg '78, 280; Brendel '87, 88; Higley and Raddin '91, 142; Huett '97, 129; Gleason '07, 182; Gleason '10, 148; Gates '12, 355.

Culms smooth, 1 to 2 feet tall; sheaths short, smooth, with conspicuous long hairs at the throat; blades short, flat, rough on the upper surface, mostly crowded at the base of the plant, 2 to 5 inches long, 3 to 5 mm. wide; panicle open, somewhat resembling that of common redtop, in autumn contracted and partly included in the sheath; spikelets usually dark colored, 2 to 2.5 mm. long.

This species is very common along the shores of Lake Michigan and thruout the sand areas of the state.

ILLINOIS SPECIMENS: Without locality, *Vasey;* Canteen lake, *Eggert*, Sept., 1886. CASS CO. Beardstown, *McDonald*, Sept., 1900. COOK CO. Chicago, *Vasey;* Chicago, *Babcock*, Oct., 1874; Evanston, *Johnston*, Sept., 1886; Chicago, *Lansing* 371; Lake View, Chicago, *Umbach*, Sept., 1898; Hyde Park, Chicago, *A. Chase*, Aug., 1899; Evanston, *Sherff*, July, 1911. HENDERSON CO. Oquawka, *Patterson* in 1881. LAKE CO. Beach Area, *Gates* 3255. LA SALLE CO. Ottawa, *Seymour*. MASON CO. Manito, *Wilcox*, July, 1902; Havana, *Gleason*, Aug., 1903. OGLE CO. Oregon, *Waite*, Sept., 1880. ST. CLAIR CO. *Eggert*, Oct., 1886.

Sporobolus drummondii (Trin.) Vasey

(Figs. 160 and 161)

Culms 1 to 2.5 feet tall, smooth; sheaths smooth; blades long and narrow, flat at base, involute at tip, 3 to 15 inches long, upper surface rough, sometimes pubescent near the base, but usually smooth; panicle seldom included in an inflated upper sheath, 3 to 6 inches long, very slender, loosely flowered, always less than half an inch wide; spikelets 4 mm. long.

This species is considerably smaller than *S. asper*, which it closely resembles.

ST. CLAIR CO. **Mascoutah, *Welsch*.** WILL CO. Gougar's Prairie, Joliet, ***Skeels*, Sept., 1904.**

Sporobolus heterolepis Gray

Northern Dropseed (Fig. 162)

Lapham '57, 545, 563 (Plate 1, Fig. 6); Babcock '73, 96; Patterson '76, 49; Flagg '78, 280; Brendel '87, 63; Higley and Raddin '91, 142; Huett '97, 129; Gleason '10, 148; Gates '12, 355.

Culms 1 to 3 feet tall, smooth, erect; sheaths smooth; blades long and narrow, rough on the upper surface; panicles 3 to 10 inches long, the branches often spreading, but sometimes erect; spikelets 4 to 6 mm. long, the first glume very much shorter and narrower than the long-pointed second glume.

This species is very distinct and hence is not likely to be mistaken for any other. It is found in dry soil. On the original prairies of the state it was abundant.

ILLINOIS SPECIMENS: Without locality, *M. S. Bebb* in 1859 and 1868; without locality, *Vasey;* without locality, *Mead;* without locality, *Hall* in 1875. CHAMPAIGN CO. Urbana, *Clinton,* Aug., 1895; Champaign, *Clinton,* Oct., 1895. COOK CO. Englewood, *Hill,* Sept., 1875. DU PAGE CO. Hinsdale, *Smith,* Sept., 1902. FULTON CO. Canton, *Wolf;* Canton, *McDonald,* Aug., 1889. JO DAVIESS CO. Warren, *Pepoon* 596. HANCOCK CO. Augusta, *Mead* in 1845. HENDERSON CO. Oquawka, *Pratt,* Oct., 1872. KANKAKEE CO. Altorf, *Hill* 199 in 1872. LAKE CO. Beach Area, *Gates* 3223. MCHENRY CO. Union, *Seymour,* Sept., 1881; Ringwood, *Vasey.* PEORIA CO. Without locality, *Brendel;* near Princeville, *V. H. Chase* 819; Peoria, *McDonald,* Sept., 1900. WABASH CO. Mt. Carmel, *Schneck,* Oct., 1876; Old Palmyra, *Schneck,* Sept., 1904. WILL CO. Joliet, *Hill* 195 in 1907. WINNEBAGO CO. Fountaindale, *M. S. Bebb* in 1868.

Sporobolus neglectus Nash

Small Rush Grass (Fig. 163)

Culms smooth, 6 to 24 inches tall, forming small bunches; sheaths inflated, broader than the blades, smooth; blades slightly longer than the sheaths, about 2 mm. wide, rough on the upper surface, usually pubescent near the base, usually involute when dry; panicles 1 to 2.5 inches long, all except the terminal panicles completely inclosed in the inflated sheaths; spikelets 2.5 to 3 mm. long, glumes, lemma, and palea all of the same texture, all white and shining.

This species has been confused with *S. vaginaeflorus,* which it resembles in general habit of growth and in the size and shape of the panicles which are inclosed in the inflated upper sheaths. *S. neglectus* is usually a smaller plant and is distinguishable by its smooth, white spikelets, those in *S. vaginaeflorus* having pubescent lemmas and not white, shiny spikelets as in *S. neglectus.*

ILLINOIS SPECIMENS: Without locality, *M. S. Bebb;* without locality, *Wolf;* without locality, *Vasey;* Lake Zurich, *Hill,* Sept., 1898; Otto, *De Selm,* Sept., 1913. CHAMPAIGN CO. Urbana, *Waite,* Sept., 1888; Urbana, *Seymour,* Oct., 1880; St. Joseph, *Clinton,* Oct., 1895. COOK CO. Chicago, *Babcock,* Oct., 1874; Evanston, *Shipman,* Oct., 1875. DU PAGE CO. Naperville, *Umbach,* Aug., 1898. FULTON CO. Without locality, *Pepoon;* Canton, *Brendel.* HANCOCK CO. Augusta, *Mead.* HENDERSON CO. Oquawka, *Patterson.* LAKE CO. Lake Zurich, *Hill,* Sept., 1898. MENARD CO. Without locality, *Hall* in 1861 and 1864; Athens, *Hall* in 1864.

OGLE CO. Without locality, *M. S. Bebb;* Oregon, *Waite,* Sept., 1888. PEORIA CO. *McDonald,* Oct., 1904; Peoria, *Brendel.* STARK CO. Duncan, *V. H. Chase,* Sept., 1906. WILL CO. Marley, *Hill,* Sept., 1895.

Sporobolus vaginaeflorus (Torr.) Wood

Sheathed Rush Grass (Fig. 164)

Vilfa vaginaeflora, Lapham '57, 544, 563 (Plate 1, Fig. 5); Babcock '73, 96; Flagg '78, 280; Brendel '87, 63. *Sporobolus vaginaeflorus,* Higley and Raddin '91, 142; Huett '97, 219.

Culms 8 to 24 inches tall, smooth; sheaths usually all inflated, smooth; blades a little longer than the sheaths, very narrow, usually involute, rough on the upper surface and pubescent near the base; lateral panicles usually inclosed in the inflated sheaths, the terminal ones usually free; spikelets 3.5 to 4 mm. long, the glumes usually white, the lemma dark colored and always pubescent.

This species resembles *S. neglectus,* but is usually larger and is easily recognized by the spikelets. It grows in dry, sandy soil.

ILLINOIS SPECIMENS: Without locality, *Wolf* in 1882; without locality, *Mead* in 1844. CHAMPAIGN CO. Urbana, *Grimes,* Sept., 1916. COOK CO. Lyons, *Hill,* Aug., 1898; Morgan Park, Chicago, *Hill,* Sept., 1898; Eggleston, *Hill* 309 in 1898. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon.* HANCOCK CO. Augusta, *Mead* in 1843. HENDERSON CO. Oquawka, *Patterson.* LAKE CO. Lake Zurich, *Hill,* Sept., 1898. MENARD CO. Without locality, *Hall.* PEORIA CO. Peoria, *McDonald,* Sept., 1900. ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase* 1209 and 1266. WABASH CO. Mt. Carmel, *Schneck,* Sept., 1876 and Oct., 1887.

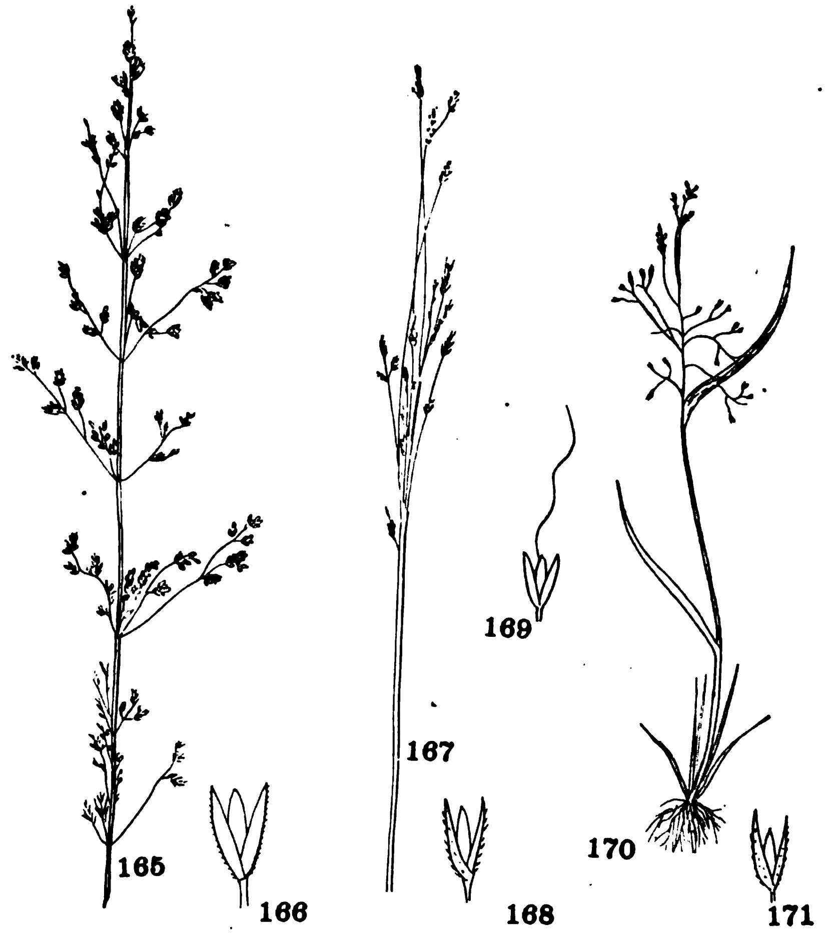
Two other species have been reported from Illinois, *S. junceus* (Higley and Raddin '91, p. 42) and *S. virginica* (*Vilfa virginica,* Patterson '76, 49; Flagg '78, 280; Brendel '87, 88). No specimens of either of these have been seen. The latter, as understood at present, is a seashore rush grass with long, stout rootstocks, and is not found inland.

27. AGROSTIS L.

Bent Grass

This genus includes both annual and perennial species. They are distinguished by the small one-flowered spikelets in which both glumes and lemma are thin, the glumes considerably the longer. The palea is minute or wanting in all Illinois species but *A. alba.* The inflorescence is always paniculate. The leaves are narrow, with conspicuous membranous ligules. *A. alba* is the only species of economic importance.

Lemma with a long awn; spikelets less than 2 mm. long. *A. elliottiana*
Lemma awnless; spikelets more than 2 mm. long.
  Palea at least half as long as the lemma. *A. alba*
  Palea minute or wanting.
    Panicle branches spreading, usually whorled, the branches long and capillary, very rough, spikelet-bearing at the tips. *A. hyemalis*
    Panicle branches ascending or spreading, but not whorled, nearly smooth, the spikelets not clustered at the tips of the branches. *A. perennans*



Figs. 165–171.—165, *A. alba,* inflorescence; 166, *A. alba,* spikelet; 167, *A. hyemalis,* inflorescence, immature; 168, *A. hyemalis,* spikelet; 169, *A. elliottiana,* spikelet; 170, *A. perennans;* 171, *A. perennans,* spikelet

Agrostis alba L.

Fiorin. White Bent. Redtop (Fig. 165)

Lapham '57, 545, 565; Patterson '76, 49; Flagg '78, 280; Brendel '87, 63; Huett '97, 130; Gates '12, 355; Sherff '12, 420; Sherff '13, 594.

Culms 1 to 4 feet tall from creeping rootstocks; sheaths smooth, blades 2 to 8 inches long, 2 to 6 mm. wide, slightly rough; ligule membranous, usually 4 to 5 mm. long; panicle spreading, contracted after flowering; spikelets 2 to 2.5 mm. long, palea present, usually half as long as the lemma.

The earlier botanists of the state assert that this species is native here, and that it is found in moist situations in prairies, fields, roadsides, ditch banks, etc. It is one of the common pasture grasses and is also cultivated for hay. A low variety is cultivated as a lawn grass under the name of creeping bent.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Champaign, *Mosher*, June, 1913; Urbana, *Seymour*, July, 1878; Urbana, *Clinton* in 1893; Urbana, *Mosher*, June, 1913. COOK CO. Without locality, *Gates*, June, 1906; Evanston, *Shipman*, July, 1875. FULTON CO. Without locality, *Pepoon;* Canton, *Brendel*. JACKSON CO. Without locality, *Lapham*. JO DAVIESS CO. Warren, *Pepoon* 24. MACOUPIN CO. Carlinville, *Robertson*, May, 1881. PEORIA CO. Peoria, *Brendel*. ST. CLAIR CO. Mascoutah, *Welsch;* East St. Louis, *Eggert*, June, 1879. STARK CO. Wady Petra, *V. H. Chase* 56. WABASH CO. Without locality, *Schneck*, June, 1900; without locality, *Shearer;* Mt. Carmel, *Schneck*, June, 1892, 1900, 1904.

Agrostis alba vulgaris Thurb.

Agrostis vulgaris, Lapham '57, 545, 566; Babcock '73, 96; Patterson '76, 49; Flagg '78, 280; Brendel '87, 63. *Agrostis alba* var *vulgaris*, Higley and Raddin '91, 142; Huett '97, 130; Cowles '00, 106.

This variety, on account of the many intergrading forms, is not easily distinguished from the species. It is usually found in dryer situations and is not so tall, from 9 to 18 inches being the average height. The panicle is smaller and usually more open and spreading. The leaves are smaller and the ligule is generally much shorter.

ILLINOIS SPECIMENS: Without locality, southern Illinois, *Vasey*. CHAMPAIGN CO. Champaign, *Clinton* in 1888; Urbana, *Seymour*, June, 1880. MENARD CO. Without locality, *Hall* in 1861. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald*, July, 1889.

Agrostis elliottiana Schultes

Elliott's Bent Grass (Fig. 169)

Plants annual; culms slender, 5 to 12 inches tall, smooth; sheaths smooth; blades rough, .5 to 5 inches long, not over 2 mm. wide; ligule about 2 mm. long; panicle narrow, somewhat open, the branches delicate; spikelets about 1.5 mm. long, the lemma bearing a slender awn about 5 mm. long.

This is a southeastern species and rare in Illinois. It grows in dry soil. So far as known it is the only awned species of Agrostis in the state.

ILLINOIS SPECIMENS: Without locality, southern Illinois, *Shimer*, May, 1893. JOHNSON CO. Tunnel Hill, *Evelyn Ridgway*, May, 1900. ST. CLAIR CO. Mascoutah, *Welsch*.

Agrostis hyemalis (Walt.) B. S. P.

Hair Grass (Figs. 167 and 168)

Agrostis scabra, Lapham '57, 545, 564; Babcock '73, 96; Patterson '76, 49; Flagg '78, 280; Brendel '87, 63; Higley and Raddin '91, 143; Huett '97, 130.

Culms slender, smooth, 1 to 2 feet tall; leaves not numerous, mostly clustered at the base of the plant, sheaths smooth, the blades rough, 2 to 5 inches long, 1 to 3 mm. wide; panicle usually purplish, with spreading, capillary, whorled, very scabrous branches spikelet-bearing at the tips; spikelets 1.5 to 2 mm. long.

This species was very abundant on the prairies, especially in the poorer kinds of soil. It prefers dry soil and is usually found now in uncultivated fields, pastures, and woodland. The panicles are usually very large, somewhat resembling those of *Panicum capillare* and like them break off at maturity and roll before the wind.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Urbana, *Seymour*, July, 1880. COOK CO. Chicago, *Babcock*, July, 1873; Chicago, *Hill* 23 in 1891. JO DAVIESS CO. Without locality, *Pepoon* 177. JOHNSON CO. Tunnel Hill, *Schneck*, May, 1902. KANKAKEE CO. *Hill*, May, 1870. MCHENRY CO. Ringwood, *Vasey*. MACOUPIN CO. Carlinville, *Robertson*, June, 1882. MARION CO. Without locality, *Lapham;* Salem, *M. S. Bebb* in 1860. MARSHALL CO. Steuben township, *V. H. Chase* 1785. PEORIA CO. Peoria, *McDonald;* Peoria, *Brendel*. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase* 56, 1200, 1442. WABASH CO. Without locality, *Schneck*, June, 1901; without locality, *Shearer;* Mt. Carmel, *Schneck*, June, 1904; vicinity of Mt. Carmel, *Schneck* in 1879, 1881, and 1890.

Agrostis perennans (Walt.) Tuckerm.

Thin Grass (Figs. 170 and 171)

Brendel '59, 585; Vasey '61, 671; Babcock '73, 96; Patterson '76, 49; Flagg '78, 280; Brendel '87, 63; Higley and Raddin '91, 142; Sherff '12, 49; Sherff '13, 594.

Culms usually very slender, erect or ascending from a decumbent base; sheaths smooth, blades rough, 2 to 6 inches long, 2 to 6 mm. wide, numerous, mostly erect; panicle variable, usually narrow and not spreading, pale green or sometimes purplish; the branches usually not whorled and not having the spikelets clustered at the ends, capillary and slightly roughened; spikelets 2 to 3 mm. long.

This species is exceedingly variable in its habit of growth, so that it is difficult to state definitely the differences between this species and *A. hyemalis*. In general, however, they are very easily distinguished. *A. perennans* grows in shady places and blooms mostly from August to October, while *A. hyemalis* blooms from May to July.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Champaign, *Gleason*, Sept., 1898; Urbana, *Clinton*, Sept., 1899 and Oct., 1895. COOK CO. Evanston, *Shipman*, Sept., 1875; Winnetka, *Sherff* 1915. FULTON CO. Canton, *Wolf;* Canton, *Brendel*. PEORIA CO. Princeville, *V. H. Chase* 1186; Peoria, *Brendel;* Peoria, *McDonald*, Aug., 1899. ST. CLAIR CO. Mascoutah, *Welsch*. UNION CO. Cobden, *Seymour*, Aug., 1880. WABASH CO. Without locality, *Shearer*, Oct., 1901; Hanging Rock, *Schneck;* Crayfish creek, *Schneck*, Oct., 1897; Mt. Carmel, *Schneck*, Sept., 1877.

28. CALAMOVILFA Hack.

These are tall, reed-like grasses which have long, stout rootstocks. They are found mostly on the sandy shores of lakes and streams. The large, spreading panicles are composed of one-flowered spikelets with firm glumes, lemma, and palea, the callus densely bearded.

Calamovilfa longifolia (Hook.) Hack.

Long-leaved Reed Grass (Fig. 172)

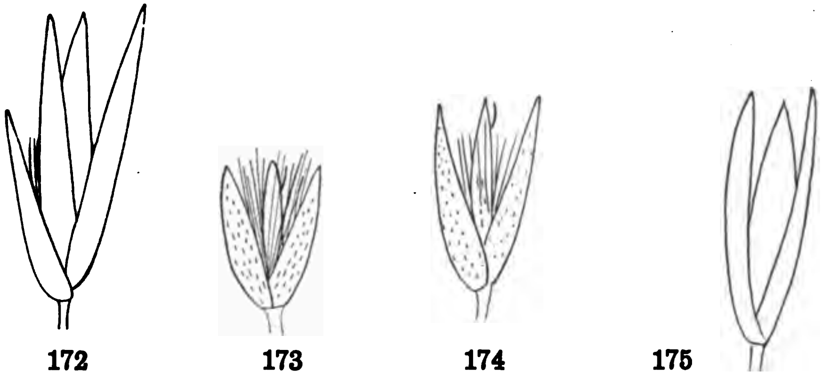
Calamagrostis longifolia, Vasey '61, 671; Babcock '73, 97; Patterson '76, 50; Flagg '78, 250; Higley and Raddin '91, 143; Huett '97, 130; McDonald '00, 103. *Calamovilfa longifolia,* Gleason '07, 182; Gleason '10, 148; Gates '12, 355.

Culms single, not branched, smooth and stout, 1 to 6 feet tall; sheaths pubescent, at least near the base and on the margin; ligule a short fringe of hairs; blades 9 to 18 inches long, involute, pointed at the end; panicle 6 to 18 inches long; spikelets 6 to 7 mm. long.

This grass is found in loose sands and is abundant along the shores of Lake Michigan, where it acts as a sand binder.

The typical form of the species, described from Saskatchewan, is a less robust plant having a narrow, strict panicle. Eggert's St. Clair collection is this typical form. The Oquawka and Lake Michigan specimens are the robust form with large, open panicles which have been distinguished as var. *magna* Scribn. and Merr.

COOK CO. Without locality, along lake shore, *Vasey;* Evanston, *Shipman,* July, 1875; Chicago, *Vasey;* Chicago, *Lansing,* July, 1898; Chicago, *Babcock,* August, 1874. HENDERSON CO. Near Oquawka, *Patterson.* LAKE CO. Waukegan, *Gleason* and *Shobe* 322; north of Waukegan, *Gates,* 2920; Waukegan, *Sherff.* MASON CO. Without locality, *M. S. Bebb.* ST. CLAIR CO. Without locality, *Eggert* in 1882.



172　173　174　175

Figs. 172–175.—Spikelets: 172, *C. longifolia;* 173, *C. canadensis;* 174, *C. inexpansa;* 175, *A. arenaria*

29. **CALAMAGROSTIS** Adans.

Reed Bent Grass

These grasses are tall, with long, running rootstocks and panicles which resemble those of Agrostis, especially *A. alba.* The spikelets are one-flowered, the lemma and palea are thinner than the glumes, the lemma awned on the back and surrounded with long hairs from the short callus at its base. The leaves are long and narrow, the ligule membranous with ragged edges.

Panicle generally open; spikelets 3 to 3.5 mm. long; lemma smooth, the callus hairs about as long as the lemma. *C. canadensis*

Panicle narrow, constricted; spikelets 4 to 4.5 mm. long; lemma rough, callus hairs about three-fourths as long as the lemma. *C. inexpansa*

Calamagrostis canadensis (Michx.) Beauv.

Blue-joint Grass (Fig. 173)

Lapham '57, 545, 568 (Plate 1, Fig. 11); Babcock '73, 97; Patterson '76, 50; Flagg '78, 280; Brendel '87, 63; Higley and Raddin '91, 130; Huett '97, 130; Gates '12, 355; Sherff '12, 419; Sherff '13, 594.

Culms 2 to 5 feet tall, smooth or slightly rough; sheaths smooth; blades 6 to 18 inches long, 2 to 8 mm. wide, rough; panicle usually widely spreading, but sometimes with the branches erect; spikelets 3 to 3.5 mm. long, the lemma smooth with an inconspicuous awn, the callus hairs almost equaling and concealing the lemma.

This species is found in wet soil, such as swamps and bogs. It is said to make excellent hay.

ILLINOIS SPECIMENS: Without locality, *Mead;* Maynard, *A. Chase,* June, 1898. CHAMPAIGN CO. Champaign, *Seymour,* June, 1884; Champaign, *Waite,* June, 1886. COOK CO. Bryn Mawr, *Meyers,* 1910; Beverly Hills, *Robert Bebb,* Aug., 1904; Chicago, *Babcock,* Aug., 1872. JO DAVIESS CO. Without locality, *Pepoon* 48. HANCOCK CO. Augusta, *Mead* in 1843. HENDERSON CO. Oquawka, *Patterson.* KANKAKEE CO. Kankakee, *Hill,* June, 1870. LAKE CO. Lake Villa, *Gleason* and *Shobe* 116, 146, 224. LIVINGSTON CO. Emington, *Wilcox,* July, 1902. MCHENRY CO. Ringwood, *Vasey.* MACOUPIN CO. Carlinville, *Robertson,* July, 1883 and 1884. MENARD CO. Athens, *Hall,* June, 1866. OGLE CO. Oregon, *Waite,* July, 1885. PEORIA CO. Princeville, *V. H. Chase,* 1897; Peoria, *Brendel;* Akron, *V. H. Chase,* June, 1897. ST. CLAIR CO. Mascoutah, *Welsch.* WHITE CO. Carmi, *Schneck,* June, 1897. WINNEBAGO CO. Without locality, *M. S. Bebb;* Fountaindale, *M. S. Bebb.*

Calamagrostis inexpansa Gray

Bog Reed Grass (Fig. 174)

Culms slender, 2 to 4 feet tall; sheaths smooth; blades rough, 8 to 12 inches long, 4 mm. wide or less; panicle narrow but not very densely flowered; spikelets 4 mm. long, awns short, lemma rough, callus hairs about two-thirds the length of the lemma.

This species is found in low, wet places.

COOK CO. Hyde Park, Chicago, *Babcock,* July, 1873.

Calamagrostis cinnoides.—This species has been reported by Lapham (*C. coarctata,* '57, 545, 568) and by Flagg (*C. nuttalliana,* 78, 280). No specimens of this have been seen by the writer.

30. **AMMOPHILA** Host

The only species in this genus is a stout perennial with strong, creeping rootstocks. It is found along the shores of Lake Michigan, where it acts as a sand binder. This grass is able to push up to the surface again after being covered by shifting sand. The inflorescence is a long, densely flowered, spike-like panicle, with one-flowered spikelets. The glumes, lemma, and palea are firm in texture, and the callus bears a ring of short hairs.

Ammophila arenaria (L.) Link

Sea Sand Grass. Psamma. Marram. Beach Grass (Fig. 175)

Calamagrostis arenaria, Vasey, '61, 671; Babcock '73, 97; Patterson '76, 50; Flagg '78, 280. *Ammophila arundinacea*, Higley and Raddin, '91, 143; Cowles, '00, 171. *Ammophila arenaria*, Gates '12, 355.

Culms smooth, 2 to 4 feet tall; sheaths smooth; blades 6 to 12 inches long, rough on the upper surface, narrowed and involute, ending in a sharp point; spikelets flattened and rough, 10 to 15 mm. long.

COOK CO. Shores of Lake Michigan, *Vasey;* shores of Lake Michigan, *Scammon*, Sept., 1860; Chicago, *Babcock*, July, 1874; Evanston, *Shipman*, July, 1879.

31. CINNA L.

Wood Reed Grass

These grasses are tall and slender, the culms growing singly or a few together. The inflorescence is of many-flowered panicles. The spikelets are one-flowered, flattened, and keeled, the glumes narrow; the lemma bears a minute awn just below the apex, but there are no hairs at the base. The palea is one-nerved or the two nerves are so close together as to appear one. The leaves are flat, the ligules brown, membranous, almost transparent, 5 to 6 mm. long.

Spikelets 3 to 4 mm. long; awn 1 to 2 mm. long; first and second glumes about equal. *C. latifolia*

Spikelets 5 to 6 mm. long; awn about .5 mm. long; first glume much shorter than the second. *C. arundinacea*

Cinna arundinacea L.

Indian Reed (Figs. 176 and 177)

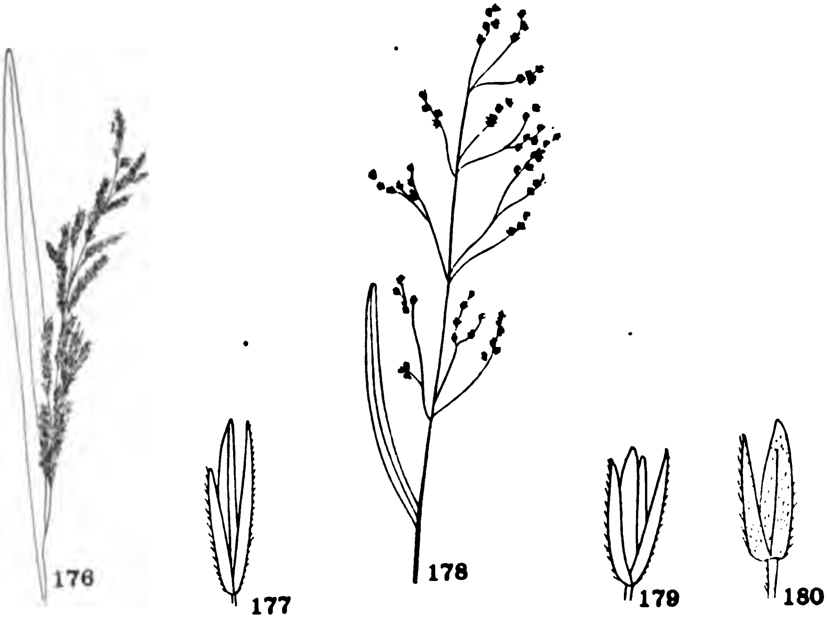
Lapham '57, 545, 565; Babcock '73, 96; Patterson '76, 49; Flagg '78, 280; Brendel '87, 63; Higley and Raddin '91, 143.

Culms 2 to 5 feet tall, smooth; sheaths smooth; blades 6 to 12 inches long, 4 to 15 mm. wide, slightly roughened; panicle usually densely flowered, the numerous branches ascending, the ends nodding; spikelets 5 to 6 mm. long, the glumes unequal, rough, the lemma with a minute awn or awnless.

This grass is found in moist, shady situations, especially in the woods. It is said to furnish excellent hay where it grows abundantly along the borders of streams.

ILLINOIS SPECIMENS: Without locality, *Vasey.* CHAMPAIGN CO. Urbana, *Clinton*, Sept., 1899; Urbana, *Seymour*, July, 1880; Urbana, *Seymour* and *Waite*, July, 1886. CHRISTIAN CO. Taylorville, *Andrews.* COOK CO. River Forest, *A. Chase*, Sept., 1900; Evanston, *Shipman*, Aug., 1875; Chicago, *Moffatt*, Aug., 1892. FULTON CO. Without locality, *Pepoon.* HENDERSON CO. Oquawka, *Patterson.* JACKSON CO. Without locality, *French* in 1878; without locality, *Lapham* in 1857.

JO DAVIESS CO. Without locality, *Pepoon* 48 and 462. KANE CO. Elgin, *Sherff,* Oct., 1909. MCHENRY CO. Algonquin, *Nason,* Aug., 1879. MACOUPIN CO. Carlinville, *Robertson,* Aug., 1880. MENARD CO. Athens, *Hall,* Sept., 1864. PEORIA CO. Glasford, *Wilcox,* Aug., 1902; Princeville, *V. H. Chase,* Sept., 1906; Peoria, *Brendel;* Peoria, *McDonald,* Aug., 1894. WABASH CO. Without locality, *Schneck,* Sept., 1876; without locality, *Shearer;* Hanging Rock, *Schneck,* Sept., 1879; Mt. Carmel, *Schneck,* Sept., 1877.



Figs. 176–180.—176, *C. arundinacea,* inflorescence; 177, *C. arundinacea,* spikelet; 178, *C. latifolia,* inflorescence; 179, *C. latifolia,* spikelet; 180, *N. lanatus,* spikelet

Cinna latifolia (Trev.) Griseb.

Slender Wood Reed Grass (Figs. 178 and 179)

Cinna arundinacea var. *pendula,* Patterson '76, 49; Flagg '78, 280.

Culms 2 to 5 feet tall, smooth; sheaths smooth; blades 6 to 12 inches long, 10 to 15 mm. wide; panicle spreading, the slender branches often drooping; spikelets 3 to 4 mm. long; glumes nearly equal, rough; lemma with a short awn.

This species is found in damp woods. It is not so abundant as *C. arundinacea.*

KANE CO. Elgin, *Vasey.* LAKE CO. Beach, *Gates,* July, 1909.

32. **NOTHOLCUS** Nash

This grass was introduced from Europe and is fairly common in the eastern United States and on the Pacific coast. The spikelets are two-flowered, the lower flower perfect, the upper staminate. The glumes and lemmas are thick; the palea very thin. The inflorescence is in dense panicles shaped something like those of Agrostis. The entire plant is covered with short, soft pubescence, hence the name velvet grass.

Notholcus lanatus (L.) Nash

Velvet Grass. Meadow Soft Grass (Fig. 180)

Holcus lanatus, Gray's Manual, 7th ed.; Britton '07, 115.

Entire plants light green and velvety; culms 1 to 3 feet tall; sheaths shorter than the internodes; blades 1 to 6 inches long, 4 to 12 mm. wide, ligule membranous, 2 to 3 mm. long; spikelets flattened, about 4 mm. long, pubescent, the glumes longer than the lemmas.

This grass is perennial. It grows best in moist places, and will thrive in very poor soil. It is a rather pretty species, with its pale green foliage and pink-tinted panicles but it is not regarded as a valuable forage grass in most places where it has been introduced. In some parts of the West, however, it is much liked.

CHAMPAIGN CO. Urbana, *Burrill*, June, 1891.

33. **SPHENOPHOLIS** Scribn.

These grasses are tall, slender, tufted perennials with narrow panicles. The leaves are flat, usually very narrow; the ligule is membranous, fringed with fine hairs, and from 2 to 4 mm. long. The species are most easily determined by the shape of the glumes, the first being very narrow and pointed, the second much broader, obovate or wedge-shaped. The spikelets are 2- to 3-flowered, and longer than the glumes.

Second glume almost as broad as long, broadly obtuse or truncate at the apex, nearly equal in length to the first. *S. obtusata*

Second glume not nearly so broad as long, acute or narrowly obtuse at the end, longer than the first. *S. pallens*

Sphenopholis obtusata (Michx.) Scribn.

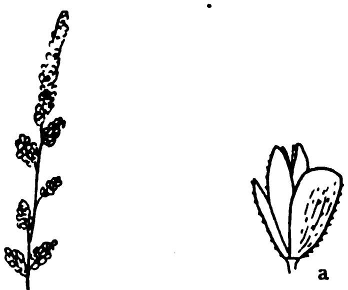
Blunt-scaled Sphenopholis (Fig. 181)

Eatonia obtusata, Lapham '57, 546, 575 (Plate 2, Fig. 10); Patterson '76, 50; Flagg '78, 281; Brendel '87, 63; Higley and Raddin '91, 143; Huett '97, 130.

Culms 1 to 3 feet tall, smooth; leaves mostly clustered at the base of the plant, sheaths rough, often pubescent; blades 1.5 to 6 inches long, 2 to 6 mm. wide, slightly rough; panicle densely flowered, 2 to 6 inches long, often so narrow as to appear spike-like; spikelets 2.5 to 3 mm. long, the glumes strongly nerved and rough except on the smooth, shiny margin; lemmas similar in texture to the glumes; palea thin and transparent.

This species is found in dry soil. It was one of the species of the original prairie and is still found in many places in the state.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Champaign, *Clinton*, June, 1900; Champaign, *Gleason* 1006. . COOK CO. Chicago, *Lansing* 272; Woodlawn, Chicago, *Lansing*, June, 1898; Englewood, *Hill*, July, 1875; South Chicago, *A. Chase*, July, 1901. CHRISTIAN CO. Taylorville, *Andrews*. FULTON CO. Without locality, *Pepoon*. HANCOCK CO. Augusta, *Mead*, June, 1848. JO DAVIESS CO. East of Warren, *Pepoon* 8. KANKAKEE CO. Bourbonnais, *Hill* 83 in 1874. MACOUPIN CO. Carlinville, *Robertson*, May, 1884. MARION CO. Without locality, *M. S. Bebb* in 1860. PEORIA CO. Peoria, *Brendel*. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase* 1156 and 1460. TAZEWELL CO. Without locality. *McDonald*, July, 1889. VERMILION CO. Muncie, *Mosher*, May, 1914. WABASH CO. Old Palmyra, *Schneck*, May, 1880; Mt. Carmel, *Schneck*, June, 1904.



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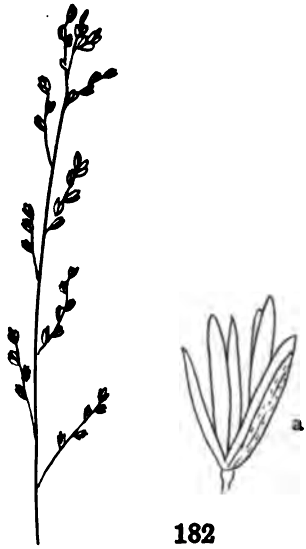

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Figs. 181–182.—181, *S. obtusata*, inflorescence, (a) spikelet; 182, *S. pallens*, inflorescence, (a) spikelet

Sphenopholis pallens (Spreng.) Scribn.
(Fig. 182)

Eatonia pennsylvanica, Lapham '57, 546, 576; Patterson '76, 50; Flagg '78, 281; Brendel '87, 63; Higley and Raddin '91, 143. *Sphenopholis pallens*, Sherff '12, 419; Sherff '13, 594.

Culms smooth, 1 to 3.5 feet tall; sheaths rough, sometimes pubescent; blades 2 to 7 inches long, 4 to 6 mm. wide, rough and sometimes with a few hairs; panicles loosely flowered, narrow, 3 to 7 inches long; spikelets 3 to 4 mm. long, glumes strongly nerved and rough except the margins; lemma firm; palea membranous, transparent.

This species was also found on the original prairie but in moist situations.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Urbana, *Burrill*, *Waite*, and *Seymour*, June, 1884; Champaign, *Waite*, June, 1886. CHRISTIAN CO. Taylorville, *Andrews*. COOK CO. Glencoe, *Sherff*, June, 1911. HENDER-

SON CO. Oquawka, *Patterson.* MCHENRY CO. Algonquin, *Nason,* June, 1878. KANKAKEE CO. Kankakee, *Hill,* June, 1873. MACOUPIN CO. Carlinville, *Robertson,* June, 1884. MENARD CO. Without locality, *Hall* in 1874; Athens, *Hall* in 1864. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* July, 1889. STARK CO. Wady Petra, *V. H. Chase* 589. WABASH CO. Without locality, *Schneck,* May, 1879; without locality, *Shearer;* Patton, *Schneck,* June, 1900; Mt. Carmel, *Schneck,* June, 1881, 1900, 1904 and 1906; Old Palmyra, *Schneck,* June, 1900. WILL CO. Joliet, *Skeels,* June, 1904.

Sphenopholis pennsylvanica (L.) Hitchc.—This species is described as *Trisetum pennsylvanicum* in Britton's Manual (1907), where it is reported from Illinois. It was also reported from Illinois by several of the earlier authors as *Trisetum palustre*: Lapham '57, 548, 589; Patterson '76, 52; Flagg '78, 284 and Brendel '87, 88. It is also reported from Illinois in Gray's Manual (7th ed.) under the name *S. palustris* (Michx.) Scribn. No Illinois specimens are contained in the herbaria examined, nor are there any in the herbarium of the New York Botanical Garden or in the Gray Herbarium.

34. KOELERIA Pers.

This genus includes a single species which was found in dry places on the western prairies. It grows in large bunches, with narrow leaves and shining, spike-like panicles which are about the length of those of timothy, but are thicker, interrupted, and not quite cylindrical. The spikelets are 2- to 4-flowered, the glumes slightly shorter than the florets.

Koeleria cristata (L.) Pers.

(Fig. 184)

Lapham '57, 546, 575; Babcock '73, 97; Patterson '76, 50; Flagg '78, 281; Brendel '87, 63; Higley and Raddin '91, 143; Gleason '10, 148; Gates '12, 355.

Culms 1 to 2.5 feet tall, densely short pubescent just below the panicle, otherwise smooth; leaves mostly clustered at the base; sheaths pubescent; ligules inconspicuous or lacking; blades 1 to 12 inches long, 1 to 5 mm. wide, generally rough and more or less pubescent, becoming involute when dry; panicle pale green and shining; spikelets rough, 4 to 5 mm. long.

ILLINOIS SPECIMENS: Without locality, *Vasey;* without locality, *Hall;* southern Illinois, *Lapham* in 1857. CHAMPAIGN CO. Champaign, *Waite,* June, 1886; Champaign, *Seymour,* June, 1884. CHRISTIAN CO. Taylorville, *Andrews.* COOK CO. Rogers Park, *Johnson,* July, 1890. FULTON CO. Without locality, *Pepoon.* JACKSON CO. Makanda, *Gleason,* June, 1903. JO DAVIESS CO. Without locality, *Pepoon,* July, 1908; Hanover, *Gleason* and *Gates* 2533. KANKAKEE CO. Kankakee, *Hill,* 47 in 1871. KNOX CO. Williamsfield, *V. H. Chase* 1842. LAKE CO. Waukegan, *Gates* 2467; Beach, *Gates* 2763; Rockefeller, *Gates* 1740. MCHENRY CO. Algonquin, *Nason,* June, 1878. MACOUPIN CO. Carlinville, *Robertson,* June, 1884. MARION CO. Without locality, *M. S. Bebb* in 1860. MARSHALL CO. Near Lawn Ridge, *V. H. Chase* 1382. PEORIA CO. Peoria, *McDonald,* June, 1890; Peoria, *Brendel.* ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. East of Wady Petra, *V. H. Chase* 28; Wady Petra, *V. H. Chase* 1382 and 1496. WABASH CO. Without locality, *Shearer.*

35. DESCHAMPSIA Beauv.

This genus belongs to cold climates; only one species has been found in Illinois. The plants are perennial with short, very narrow or involute leaves clustered at the base, and, borne far above them, a loose, open panicle with shining spikelets, which are brown, tinged with purple. The spikelets are mostly 2- rarely 3-flowered, the glumes and lemmas thin, the lemma bearing an awn from near its base.

Deschampsia caespitosa (L.) Beauv.

Tufted Hair Grass (Figs. 183 and 185)

Aira caespitosa, Vasey '61, 671; Flagg '78, 284.

Culms in tufts 2 to 4 feet tall, smooth; sheaths smooth; ligule membranous, transparent, 3 to 5 mm. long; blades usually flat, becoming involute when dry, rough on the upper surface, 1 to 6 inches long, 2 to 3 mm. wide; panicle 4 to 8 inches long, usually half as wide, the branches not numerous, slender, rough and spikelet-bearing at the ends; spikelets 3.5 to 4 mm. long, the glumes usually as long as the lemma, the awn extending slightly beyond the glumes. This species is found in moist soil, usually along streams.

ILLINOIS SPECIMENS: Without locality, *Vasey* in 1861; northern Illinois, *Vasey*. KANE CO. Elgin, *Vasey*.

36. AVENA (Tourn.) L.

Oat

Two species of oat, both annuals, may be found in Illinois—the wild and the cultivated. The latter often escapes from cultivation and may be found in waste places, but it seldom establishes itself. The genus is distinguished by its large, open panicles with spikelets from half an inch to an inch long. The spikelets are 2- to 4-flowered, the many-nerved glumes longer than the lemmas, which usually bear a dorsal awn. The leaves are long and flat, the ligule membranous, 1 to 4 mm. long.

Lemmas pubescent; awn well developed, twisted at the base.	*A. fatua*
Lemmas smooth; awn, if present, small, usually straight.	*A. sativa*

Avena fatua L.

Wild Oat (Fig. 186)

Culms stout, 1 to 4 feet tall, smooth; sheaths usually smooth, sometimes slightly roughened near the blade, occasionally hairy; blades slightly roughened, 3 to 12 inches long, 4 to 14 mm. wide; panicle 4 to 12 inches long, usually narrow, the branches ascending; spikelets 22 to 25 mm. long, excluding the awns, the lemmas sparsely covered with long brown hairs, which are more numerous near the base; awn arising from near the middle of the lemma, twisted at base.

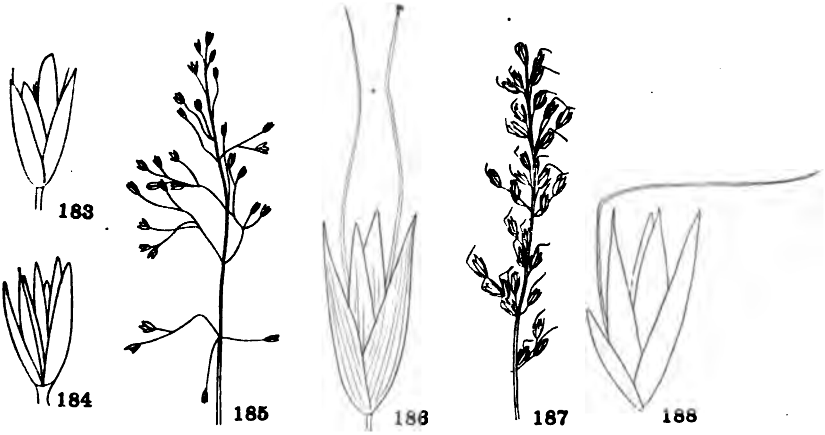
This species is a common weed in the West, but it has been reported from only one locality in Illinois.

DU PAGE CO. Naperville, *Umbach*, July, 1896 and 1898; Naperville, *Moffatt*, Aug., 1894.

Avena sativa L.

This species is too well known to need description. Under cultivation the awn is obsolete, but in specimens found in waste places, it is often fairly well developed. Such specimens may be distinguished from *A. fatua* by the nearly glabrous lemma.

CHAMPAIGN CO. Champaign, *Clinton*, July, 1900; Champaign, *Seymour*, July, 1880. COOK CO. Chicago, *Lansing*, July, 1898. LAKE CO. Channel lake, *Haynes*, Aug., 1905. PEORIA CO. Peoria, *Brendel*. ST. CLAIR CO. Mascoutah, *Welsch*.



Figs. 183–188.—183, *D. caespitosa*, spikelet; 184, *K. cristata*, spikelet; 185, *D. caespitosa*, inflorescence; 186, *A. fatua*, spikelet; 187, *A. elatius*, inflorescence; 188, *A. elatius*, spikelet

37. **ARRHENATHERUM** Beauv.

Oat Grass

This genus is commonly called oat-grass on account of its spikelets, which closely resemble those of the oat but are considerably smaller. The plants are perennial with long, flat leaves and narrow panicles. The spikelets are 2-flowered, one floret perfect, awnless or with a short awn, the other staminate, awned, the awn bent, twisted near the base.

Arrhenatherum elatius (L.) Beauv.

Tall Oat Grass. Randall Grass (Figs. 187 and 188)

Culms smooth, 3 to 4 feet tall; sheaths smooth; blades rough, 2 to 12 inches long, 2 to 8 mm. wide; ligule membranous, about 1 mm. long, panicle 4 to 12 inches long, narrow, the branches ascending; spikelets 7 to 8 mm. long, the lemma rough, its awn about twice as long.

This species was introduced from Europe as a meadow grass. It often escapes from cultivation. So far as known it has never been extensively cultivated in Illinois.

CHAMPAIGN CO. Urbana, *Burrill*, July 1878. COOK CO. Hyde Park, *Hill* 217 in 1894. PEORIA CO. Peoria, *McDonald*, July, 1903.

38. DANTHONIA DC.

This genus is distinguished by its narrow, spike-like panicles which consist of very few spikelets. The leaves are mostly clustered at the base, very short, narrow, and usually involute. The spikelets are 3- to 8-flowered, the florets usually all perfect. The glumes are much longer than the lemmas, usually extending beyond all the florets. The lemmas are toothed at the end with a flat, twisted awn between the teeth. Only one species is found in Illinois.

Danthonia spicata (L.) Beauv.

Wild Oat Grass (Figs. 191 and 192)

Lapham '57, 547, 589 (Plate 4, Fig. 1); Patterson '76, 52; Flagg '78, 283; Brendel '87, 64; Higley and Raddin '91, 143; Huett '97, 130; Sherff '12, 420; Sherff '13, 595.

Culms smooth, 8 to 28 inches tall; sheaths usually pubescent especially at the throat; ligule very short, mostly a fringe of hairs, 1 to 2 mm. long; blades narrow, somewhat curled, usually involute, 1 to 6 inches long, 1 to 2 mm. wide; spikelets 10 to 12 mm. long, 3- to 8-flowered, the glumes smooth, the lemmas pubescent, 4 to 5 mm. long; awn longer than the lemma.

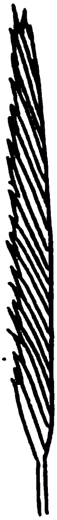
This species grows in small tufts. It is found in dry, usually sterile soil.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Urbana, *Seymour* and *Waite*, July, 1886. CHRISTIAN CO. Taylorville, *Andrews*. COOK CO. West Chicago, *Umbach*, June, 1897; Evanston, *Gates*, June, 1900; Beverly Hills, *R. Bebb*, June, 1902. FULTON CO. Without locality, *Pepoon*. HANCOCK CO. Augusta, *Mead* in 1845. JACKSON CO. Without locality, *French*, May, 1905; Makanda, *Gleason*, June, 1903. JO DAVIESS CO. Without locality, *Pepoon*. MACOUPIN CO. Carlinville, *Robertson* in 1881. MARION CO. Without locality, *M. S. Bebb* in 1860. MARSHALL CO. Steuben township, *V. H. Chase* 1789. PEORIA CO. Peoria, *McDonald* 28; Peoria, *McDonald*, June, 1887; Peoria, *Brendel*. ST. CLAIR CO. Mascoutah, *Welsch*. UNION CO. Cobden, *Waite*, June, 1885. VERMILION CO. Muncie, *Mosher*, Sept., 1914. WILL CO. Joliet, *Skeels*, July, 1904, Mokena, *A. Chase*, June, 1897.

39. SPARTINA Schreb.

Cord or Marsh Grass

These grasses are tall, coarse perennials with stout, creeping rootstocks, found in marshes and sloughs and along the borders of streams and lakes. The inflorescence consists of spikes formed of 1-flowered, flattened spikelets which closely overlap each other on one side of the rachis.



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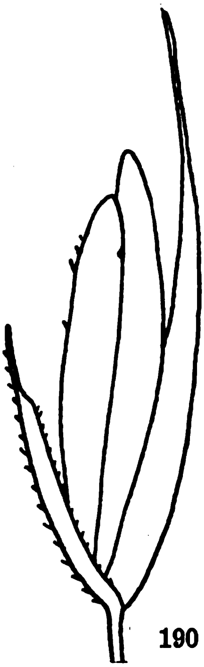

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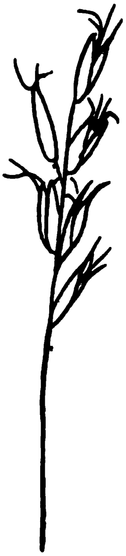

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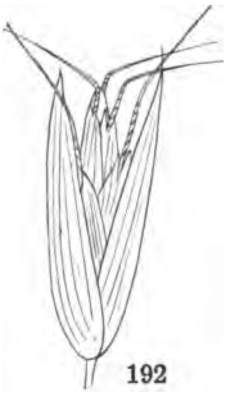

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Figs. 189–192.—189, *S. michauxiana,* inflorescence; 190, *S. michauxiana,* spikelet; 191, *D. spicata,* inflorescence; 192, *D. spicata,* spikelet

Spartina michauxiana Hitchc.

Slough Grass. Fresh Water Cord Grass (Figs. 189 and 190)

***Spartina cynosuroides,* Lapham '57, 545, 571 (Plate 2, Fig. 3); Babcock '73, 97; Patterson '76, 50; Flagg '78, 281; Brendel '87, 63; Higley and Raddin '91, 138; Huett '97, 128; Gleason '07, 182. *Spartina michauxiana,* Gleason '10, 148; Gates '12, 355; Gleason '12, 45; Sherff '13, 595.**

Culms smooth, 3 to 6 feet tall; sheaths smooth; ligule mostly a fringe of hairs 2 to 3 mm. long; blades sharp-pointed, 2 to 4 feet long, 6 to 15 mm. wide, rough along the edges and usually involute when dry; spikes 1 to 4 inches long; spikelets 7 to 9 mm. long, the first glume about half as long as the awned second glume.

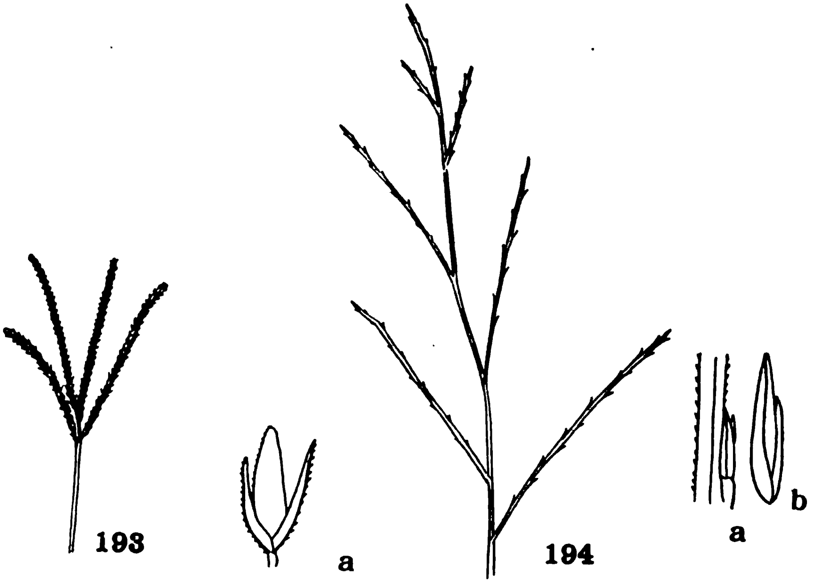
This is one of the native grasses that appear to be almost as abundant today as when the country was first settled. If cut early it makes fairly good hay. Its rootstocks make it valuable also as a sand binder.

ILLINOIS SPECIMENS: Without locality, *Vasey.* CHAMPAIGN CO. Without locality, *Percival;* Savoy, *Gibbs,* Sept., 1898; near Mahomet, *Burrill* and *Seymour,* Aug., 1880. COOK CO. Hyde Park, Chicago, *Babcock,* July, 1874; Thornton, *Hill,* July, 1865. CHRISTIAN CO. Taylorville, *Andrews.* DU PAGE CO. Wheatland, *Umbach,* July, 1909. FULTON CO. Without locality, *Pepoon;* Canton, *Wolf.* JO DAVIESS CO. Without locality, *Pepoon.* KANKAKEE CO. Kankakee, *De Selm,* Aug., 1913; Kankakee, *Hill,* July, 1873. LAKE CO. Beach, *Umbach,* July, 1909; Lake

Villa, *Gleason* and *Shobe* 226; beach area near Waukegan, *Gates* 2913. MENARD CO. Athens, *Hall* in 1861. OGLE CO. Oregon, *Waite*, Aug., 1888. PEORIA CO. Peoria, *McDonald;* Peoria, *Brendel.* ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase* 708. WABASH CO. Without locality, *Shearer;* Keensburgh, *Schneck*, Aug., 1880; Mt. Carmel, *Schneck*, Oct., 1906. WILL CO. Joliet, *Skeels*, Aug., 1904.

40. CAPRIOLA Adans.

This genus belongs to the Old World; one species has been introduced into the southern states, where it is now very common. It does not grow very tall. The inflorescence, much like that of crab grass, consists of several digitate spikes. It spreads by creeping rootstocks under the surface or by runners on top, and in soft, mellow soil it grows very large and coarse, making a troublesome weed. In firm soil it is fine and makes a good lawn or pasture grass. The spikelets are one-flowered, flattened, the glumes shorter than the lemma.



Figs. 193–194.—193, *C. dactylon*, inflorescence, (a) spikelet; 194, *S. paniculatus*, inflorescence, (a) portion of rachis and spikelet, (b) spikelet

Capriola dactylon (L.) Kuntze

Bermuda Grass. Scutch Grass (Fig. 193)

Cynodon dactylon, Huett '97, 130.

Culms 4 to 24 inches high, smooth; sheaths smooth or sometimes pubescent; ligule very short, mostly a fringe of hairs; blades short, pointed, 1 to 4 inches long, 2 to 4 mm. wide, more or less roughened; infloresence in spikes, 3 to 6, spread out finger-like, the spikelets sessile along one side of a slender, flat rachis; spikelets 2 to 2.5 mm. long, the lemmas hairy on the keel.

This grass may be easily identified by its pale, gray-green foliage and its creeping habit. It does not seem to be very extensively introduced into Illinois. Mr. R. Pike of St. Jacob, who sent some to the University for identification, reports that it started a very few years ago in that locality and has spread at a very rapid rate. Care should be taken not to allow it to obtain a foothold in cultivated fields.

COOK CO. Chicago, *Moffat,* Sept., 1895. MADISON CO. St. Jacob, *Pike,* May, 1915. WABASH CO. Mt. Carmel, *Schneck,* July, 1898.

41. SCHEDONNARDUS Steud.

In this genus the inflorescence consists of long, narrow spikes arranged alternately along an angled axis, the rachis hollowed out on the sides, the one-flowered, narrow, sessile spikelets appressed in the hollows. The leaves are short and narrow and usually clustered at the base. The plants are annuals.

Schedonnardus paniculatus (Nutt.) Trel.

(Fig. 194)

Lepturus paniculatus, Lapham '57, 547, 585 (Plate 3, Fig. 6); Patterson '76, 51; Flagg '78, 282; Brendel '87, 88.

Culms in tufts, rough, 8 to 18 inches tall; sheaths flattened, smooth or slightly rough; ligule membranous, pointed; blades flat, rough, 1 to 4 inches long, 1 to 2 mm. wide; spikes arranged alternately, the axis and rachises sharply angled; spikelets 3 to 4.5 mm. long, rough.

It is extremely improbable that this species is now found in Illinois. It was found on the original prairie, especially around salt licks.

ILLINOIS SPECIMENS: Without locality, *Vasey.* HANCOCK CO. Augusta, *Mead;* Deer Lick, Augusta, *Mead,* Aug., 1845.

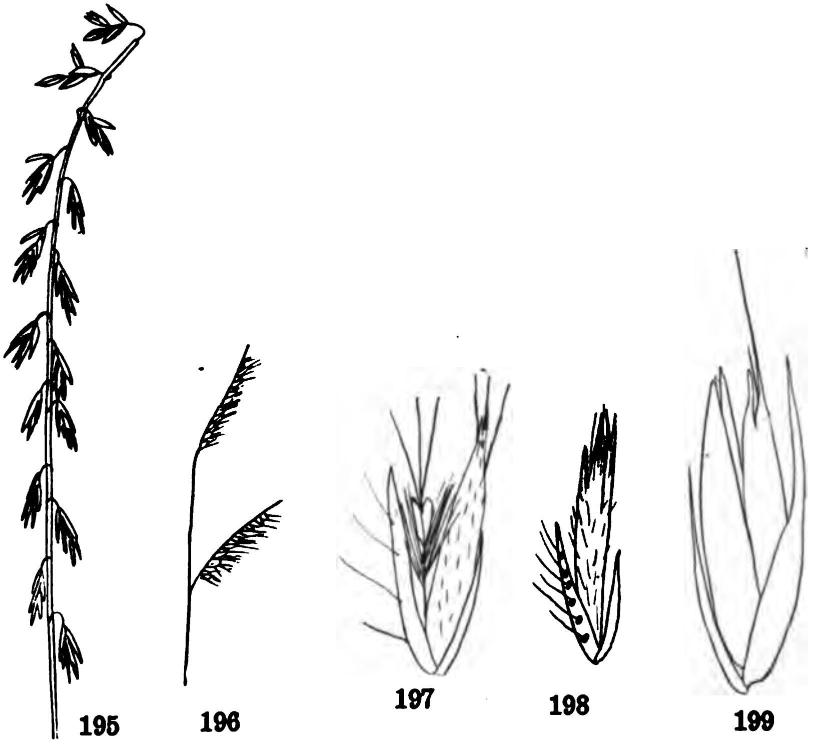
42. BOUTELOUA Lag.

Mesquite Grass. Grama Grass

These grasses are perennial and on the original prairie were important grazing grasses. The inflorescence consists of small, one-sided spikes composed of spikelets sessile on a narrow rachis, which is sometimes prolonged beyond the spikelets. The spikelets are usually 2-flowered but only the lower floret is perfect. The glumes are unequal, keeled, and usually shorter than the lemmas. The leaves are short and narrow, often involute. The ligules are very short and inconspicuous.

Inflorescence of numerous short spikes arranged on each side of the axis, drooping on slender peduncles. *B. curtipendula*
Inflorescence of 1 to 3 spikes usually on one side of the stem, ascending.

Rachis of the spike projecting beyond the spikelets in a prominent point; keel of the second glume pubescent, the hairs from prominent black papillae; the sterile lemma not with a tuft of hairs at the base. *B. hirsuta*
Rachis of the spike not projecting beyond the spikelets; keel of the second glume glabrous or with few hairs, these not from papillae; sterile lemma with a tuft of hairs at the base. *B. gracilis*



Figs. 195–199.—195, *B. curtipendula,* inflorescence; 196, *B. hirsuta,* inflorescence; 197, *B. gracilis,* spikelet; 198, *B. hirsuta,* spikelet; 199, *B. curtipendula,* spikelet

Bouteloua curtipendula (Michx.) Torr.

Tall Grama Grass. Mesquite Grass. Side-oat. Grama
(Figs. 195 and 199)

Chloris curtipendula, Michaux '03, 59. *Atheropogon apludioides,* Engelmann '44, 104; Lapham '57, 546, 572. *Bouteloua curtipendula,* Patterson '76, 50; Flagg '78, 281; Brendel '87, 63; Huett '97, 130. *Atheropogon curtipendulus,* Gleason '07, 182. *Bouteloua curtipendula,* Gleason '10, 148.

Culms 1 to 3 feet tall, smooth; sheaths smooth, hairy at the throat; blades slightly rough, sometimes pubescent at base, 2 to 12 inches long, 2 to 4 mm. wide; spikes short, numerous, arranged on either side of the axis, each consisting of from 5 to 8 spikelets; spikelets 7 to 10 mm. long.

This was one of the important grasses of the prairie and it is still found thruout the state. It is an excellent forage grass.

CASS CO. Chandlerville, *Seymour,* Aug., 1886. CARROLL CO. Savanna, *A. Chase* 1886. CHAMPAIGN CO. Experiment Station, Urbana, *Clinton,* Oct., 1897. COOK CO. Summit, *Umbach,* July, 1901; Palatine, *Gates* 1895.2. DU PAGE CO. Without locality, by railroad track, *Moffatt,* Aug., 1891. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon,* Aug., 1908; HENDERSON CO. Oquawka, *Patterson.* KANKAKEE CO. Kankakee, *De Selm,* Oct., 1913; Kankakee, *Hill,* July, 1874. MCHENRY CO. Algonquin, *Nason,* Aug., 1878. MASON CO. Manito, *Wilcox,* July, 1902; Havana, *Gleason,* Aug., 1903. MENARD CO. Athens, *Hall* in 1862 and 1864. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* Aug., 1887; Princeville, *V. H. Chase* 1875. OGLE CO. Oregon, *Waite,* Sept., 1887. ST. CLAIR CO. Mascoutah, *Welsch.* WILL CO. Troy township, *Hill,* Sept., 1906; Joliet, *Skeels,* Sept., 1904. WINNEBAGO CO. Fountaindale, *M. S. Bebb.* WOODFORD CO. Kappa, *Seymour,* Sept., 1879.

Bouteloua gracilis H. B. K.

(Fig. 197)

Bouteloua oligostachya, Patterson '76, 50; Flagg '78, 281; Brendel '87, 88; Gleason '10, 149.

Culms erect, 6 to 20 inches tall; sheaths smooth; blades smooth, 1 to 5 inches long, about 2 mm. wide, often involute; spikes 1 to 3, 2 to 5 cm. long; spikelets 5 to 6 mm. long; glumes narrow, the first about half as long as the second, which is glabrous or has a few long hairs on the keel; fertile lemma split up into three points at the summit, each of these with a short awn; sterile lemma with two lobes at the end and three short awns, with a tuft of long hairs at the base.

This species has the general appearance of *B. hirsuta.* It is a prairie species found in the same situations as the other species of the genus, tho it is much less common.

JO DAVIESS CO. Without locality, *Pepoon* 173.

Bouteloua hirsuta Lag.

Hairy Mesquite. Black Grama (Figs. 196 and 198)

Atheropogon papillus, Engelmann '44, 104. *Chondrosium hirtum,* Lapham '57, 571 (Plate 2, Fig. 4). *Bouteloua hirsuta,* Vasey '61; Patterson '76, 50; Flagg '78, 281; Brendel '87, 88; McDonald '00, 103; Gleason '10, 148.

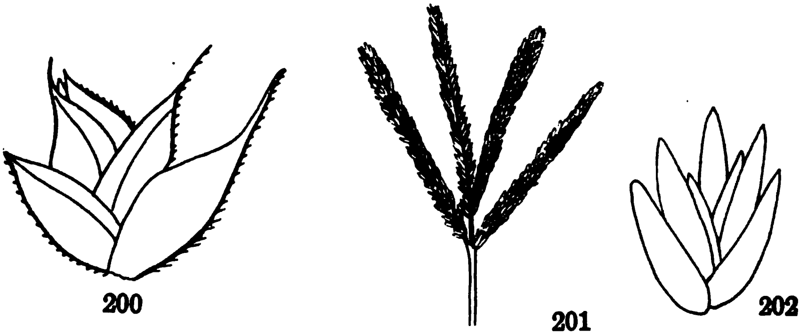
Culms 8 to 20 inches tall, the leaves crowded at the base; sheaths usually smooth, sometimes prominently papillose-pubescent; blades 1 to 5 inches long, 2 to 3 mm. wide, sparsely ciliate on the margins, usually involute when dry; spikes single or at most 2 or 3, 1 to 2 inches long, the rachis extending as a prominent point beyond the spikelets; spikelets 5 to 6 mm. long, the glumes with prominent, usually black papillae, bearing long hairs, the lemma split up into three awn-like points, the sterile floret bearing three awns.

This species is found on sandy prairie ground, tho it does not extend as far north as *B. curtipendula.* Like that species it is a good forage grass.

ILLINOIS SPECIMENS: Without locality, *Vasey;* without locality, *Mead* in 1845; along the Mississippi river, *Wilcox.* CASS CO. Beardstown, *Geyer,* Aug., 1862. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon* 160. HENDERSON CO. Without locality, *Patterson,* Aug., 1871; Oquawka, *Patterson,* Sept., 1872. MASON CO. Without locality, *Bebb* in 1861; without locality, *Hall* in 1861; Manito, *Wilcox,* July, 1902; Havana, *Gleason,* Aug., 1903. MENARD CO. Athens, *Hall* in 1860. OGLE CO. Oregon, *Waite,* Aug., 1884.

43. DACTYLOCTENIUM Willd.

One species of this genus was introduced from the warmer parts of the Old World and is found in the southern part of the state. Both in habit and in general appearance it is somewhat like *Eleusine indica,* having spikes arranged in the same manner (Fig. 201). It may readily be distinguished by the prolonged rachis which forms a point beyond the spikelets. The spikelets are flattened, 3- to 5-flowered, sessile. The glumes are broad and keeled, the lemmas sharply pointd. The leaves are flat and narrow.



Figs. 200–202.—200, *D. aegypticum,* spikelet; 201, *E. indica,* inflorescence; 202, *E. indica,* spikelet

Dactyloctenium aegypticum (L.) Willd.

Egyptian Grass. Crowfoot Grass (Fig. 200)

Lapham '57, 546, 572; Patterson '76, 50; Flagg, '78, 281.

Culms 6 inches to 2 feet tall, usually spreading and rooting at the lower nodes; sheaths very loose, smooth; blades 3 to 6 inches long, 2 to 6 mm. wide, usually pubescent near the base, especially along the edge; spikelets 3 to 4 mm. long.

This grass is an annual and is found mostly in waste places. It has been reported from several localities, altho but a single specimen has been seen by the writer.

ST. CLAIR CO. Along railway track, *Eggert,* Aug., 1876.

44. ELEUSINE Gaertn.

Grasses belonging to this genus are not native to America, and only one species has been introduced into Illinois. It has an inflorescence of spikes, spreading out finger-like at the top of the culm, as have common crab grass and Bermuda grass (Figs. 29 and 193). The spikelets each have several flowers, arranged in two rows on each side of the stem. The glumes are flattened and keeled and shorter than the spikelet. The leaves are flat, the ligules practically wanting.

Eleusine indica (L.) Gaertn.

Wire Grass. Goose Grass. Yard Grass. Crow's Foot
(Figs. 201 and 202)

Lapham '57, 546, 573 (Plate 2, Fig. 5); Patterson '76, 50; Flagg '78, 281.

Culms 6 inches to 2 feet tall, in large tufts, often spreading; sheaths loose, hairy at the throat; blades 3 to 12 inches long, 2 to 6 mm. wide, usually smooth; spikes 1 to 3 inches long; spikelets 3- to 6-flowered, 4 to 5 mm. long.

This grass is found as a weed in dooryards and waste places, where it often spreads and forms a dense mat on the surface which is extremely hard to cut. The plants are annuals, introduced from the warmer countries of the Old World. They may be eradicated by the same method used for crab grass, *Syntherisma sanguinalis*. Dr. Brendel collected it in 1873 in Peoria. His record was the first for that locality.

CHAMPAIGN CO. Champaign, *Seymour,* July, 1880; Urbana, *Mosher,* July, 1914; Urbana, *Gibbs,* Oct., 1898; Urbana, *Gates,* Oct., 1907; Urbana, *Burrill,* Sept., 1878. CHRISTIAN CO. Taylorville, *Andrews.* COOK CO. Chicago, *Umbach,* Aug., 1898. EDWARDS CO. Albion, *Waite,* Aug., 1887. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon.* HENDERSON CO. Oquawka, *Patterson,* Aug., 1877. KANKAKEE CO. Kankakee, *De Selm,* Sept., 1913. MACOUPIN CO. Carlinville, *Robertson* in 1881. MARION CO. Without locality, *M. S. Bebb* in 1860. PEORIA CO. Without locality, *Brendel;* Peoria, *McDonald,* Aug., 1885 and 1900. POPE CO. Herod, *Clinton,* Aug., 1898. WABASH CO. Without locality, *Shearer;* Mt. Carmel, *Schneck,* Aug., 1879; Hurd's Ferry, *Schneck,* June, 1904; Mt. Carmel, *Patterson,* Sept., 1877.

45. LEPTOCHLOA Beauv.

The species of Leptochloa may be recognized by their peculiar inflorescence consisting of a large, open panicle formed of numerous very slender spikes. The spikelets are several-flowered, flattened, with keeled glumes and lemmas. The leaves are flat, the ligules membranous, 3 to 4 mm. long, irregular on the edge, and fringed. Two species, both annuals, were found on the original prairie in Illinois, but they are probably rare in the state at present.

Sheaths pubescent; spikelets minute, usually 1.5 to 2 mm. long; the first floret not longer than the second glume. *L. filiformis*
Sheaths smooth, spikelets 2.5 to 8 mm. long; first floret always longer than the second glume, which is about 3 mm. *L. fascicularis*

Leptochloa fascicularis (Lam.) Gray

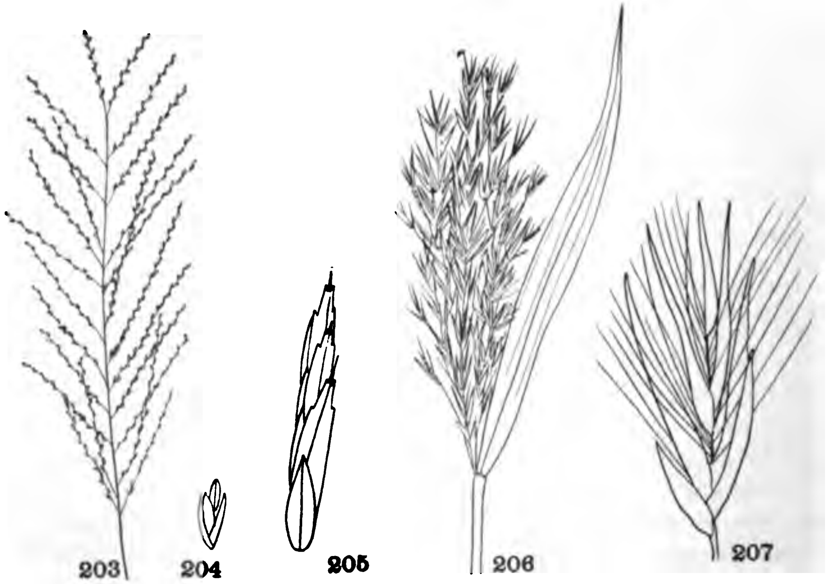
(Fig. 205)

Festuca polystachya, Michaux '03, 66. *Leptochloa fascicularis*, Lapham '57, 546, 573; Patterson '76, 50; Flagg '78, 281. *Diplachne fascicularis*, Brendel '87, 88.

Culms in tufts, smooth, 8 to 24 inches tall, occasionally taller; sheaths smooth; blades 3 to 10 inches long, 2 to 10 mm. wide; spikes 3 to 5 inches long, the whole inflorescence 6 to 20 inches long; spikelets 7- to 11-flowered, with very short stalks, glumes unequal, the second about 3 mm. long; lemmas short awned, about 4 mm. long, ciliate on the margin near the base.

Michaux first found this plant in Illinois. It grows on wet prairie soil, along ditches, and in damp meadows.

ILLINOIS SPECIMENS: Southern Illinois, *Brendel;* ponds in Illinois near St. Louis, *Smith;* near Cahokia Mound, *Ward,* Aug., 1878. MACOUPIN CO. Carlinville, *Robertson,* July, 1882. ST. CLAIR CO. Without locality, *Brendel* in 1850; Mascoutah, *Welsch.* WABASH CO. Without locality, *Schneck,* July, 1880; near L. E. and St. L. railway, *Schneck,* June, 1900.



Figs. 203–207.—203, *L. filiformis*, inflorescence; 204, *L. filiformis*, spikelet; 205, *L. fascicularis*, spikelet; 206, *P. communis*, inflorescence; 207, *P. communis*, spikelet

Leptochloa filiformis (Lam.) Beauv.

(Figs. 203 and 204)

Leptochloa mucronata, Lapham '57, 546, 573; Patterson '76, 50; Flagg '78, 281.

Culms smooth, 16 inches to 4 feet tall; sheaths papillose-pubescent; blades smooth or slightly pubescent underneath, 4 to 10 inches long, 2 to 10 mm. broad; spikes 2 to 4 inches long, the whole inflorescence 4 to 12 inches long; spikelets small, 1 to 2.5 mm. long; glumes subequal, as long as the first floret, lemma awnless.

This species occurs in drier places than does *L. fascicularis.* It is usually found in fields.

ILLINOIS SPECIMENS: Without locality, *Hall;* wet places in Illinois, *Eggert,* Sept., 1877; southern Illinois, *Brendel.* MENARD CO. Athens, *Hall* in 1873. PULASKI CO. Mound City, *Vasey.* WABASH CO. Without locality, *Schneck,* July, 1880.

46. **PHRAGMITES** Trin.

These tall reed-like perennials rarely perfect seed, but spread by rootstocks which run for many feet underground. The inflorescence is of large panicles of 3- to 7-flowered spikelets, the rachilla joints densely covered with long, white, silky hairs. The leaves are rather broad and thick, narrowed to a sharp point. The ligules are short and thick, edged with a fringe of short hairs sparsely interspersed with long ones.

Phragmites communis Trin.

Reed (Figs. 206 and 207)

Lapham '57, 547, 584 (Plate 3, Fig. 4); Babcock '73, 97; Patterson '76, 51; Flagg '78, 282; Brendel '87, 64; Higley and Raddin '91, 143; Huett '97, 130; Cowles '00, 155; Sherff '12, 418; Gates '12, 355; Sherff, '12, 418.

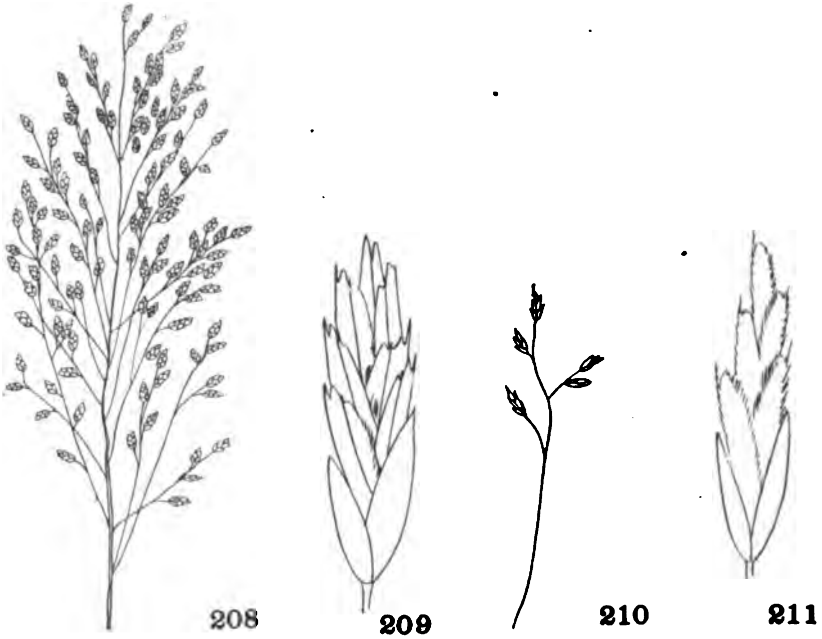
Plants smooth thruout; culms stout, 4 to 12 feet tall; sheaths overlapping, blades 6 to 12 inches long, 1 to 5 cm. wide; panicle 6 to 12 inches long, yellowish brown; spikelets 12 to 15 mm. long; first floret usually staminate, its lemma longer than that of the other florets.

The plants are found in wet places, along the edges of ditches, ponds, etc., and in swamps.

ILLINOIS SPECIMENS: Without locality, *Vasey.* CHAMPAIGN CO. Rantoul, *Clinton,* Sept., 1897. COOK CO. Chicago, *Babcock,* Sept., 1874; Evanston, *Shipman* in 1875; Colehour, *Hill,* Sept., 1876. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon.* LAKE CO. Beach, *Gates,* 3166; Fox lake, *Waite,* Sept., 1887; Lake Villa, *Gleason* and *Shobe,* Aug., 1906. LIVINGSTON CO. Emington, *Wilcox,* July, 1902. MCHENRY CO. Algonquin, *Nason.* OGLE CO. Oregon, *Waite,* Sept., 1886. PEORIA CO. Peoria, *McDonald,* Sept., 1890; Peoria, *Brendel.* ST. CLAIR CO. Mascoutah, *Welsch;* French Village, *Eggert,* Sept., 1892.

47. **TRIDENS** Roem. and Schult.

In this genus the spikelets are 5- to 8-flowered, with nearly all the florets perfect. The lemmas have a short awn at the apex with a sharp tooth on each side, and the midnerve and lateral nerves are densely hairy for about half their length. The leaves are flat, long, and narrow; the ligule is a fringe of short hairs.



Figs. 208–211.—208, *T. flavus,* inflorescence; 209, *T. flavus,* spikelet; 210, *T. purpurea,* inflorescence; 211, *T. purpurea,* spikelet

Tridens flavus (L.) Hitchc.

Tall Redtop (Figs. 208 and 209)

Poa seslerioides, Michaux '03, 68. *Tricuspis seslerioides,* Lapham '57, 546, 574 (Plate 2, Fig. 7); Patterson '76, 50; Flagg '78, 281; Brendel '87, 63; Gleason '07, 182. *Tridens flavus,* Gleason '10, 149.

Culms slightly flattened, smooth, 3 to 6 feet tall; sheaths hairy at the throat; blades rough, 4 to 12 inches long, 6 to 12 mm. wide, narrowed to a sharp point at tip; panicle 6 to 18 inches long, the long branches drooping, usually deep purple, sometimes reddish; spikelets 7 to 8 mm. long.

This species is very striking and handsome with its large purple panicles. It has a yellow form, but no Illinois specimens of this have been seen. When in bloom, the panicle, axis, and branches are covered with a viscid, oily substance, which makes them very sticky. This species was one of the grasses of the original prairie, and is still quite abundant thruout the state.

ILLINOIS SPECIMENS: Without locality, southern Illinois, *Vasey*. ADAMS CO. Quincy, *Bebb*, July, 1860. CASS CO. Chandlerville, *Seymour*, Aug., 1886. CHRISTIAN CO. Taylorville, *Andrews*. HENDERSON CO. Oquawka, *Patterson*. JACKSON CO. Carbondale, *Seymour*, Aug., 1880. JERSEY CO. Grafton, *Seymour*. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald*, Aug., 1895 and Sept., 1903. ST. CLAIR CO. Without locality, *Eggert*, Sept., 1886; Mascoutah, *Welsch*. UNION CO. Cobden, *Seymour*, Aug., 1880. WABASH CO. Without locality, *Shearer*.

48. TRIPLASIS Beauv.

These grasses are perennials with small panicles of 2- to 6-flowered spikelets which have the three nerves of the lemma, as well as the palea, densely hairy. The glumes are unequal and keeled, the lemmas are toothed at the end, somewhat like Tridens. The leaves are long, very narrow, and usually involute. The ligule is a fringe of hairs 1 to 2 mm. long.

Triplasis purpurea (Walt.) Champ.

Sand Grass (Figs. 210 and 211)

Tricuspis purpurea, Patterson '76, 50; Flagg '78, 281. *Triplasis purpurea*, Brendel '87, 88. *Tricuspis purpurea*, Gleason '10, 149.

Culms in tufts 1 to 2 feet high, smooth; sheaths loose, shorter than the internodes; blades small, rough on the upper surface, 1 to 3 inches long, not over 3 mm. wide, usually involute; panicles 1 to 3 inches long, usually purplish, late in the season inclosed in the upper sheaths; spikelets 5 to 8 mm. long, the awn of the lemma very short.

This grass is most abundant in sandy places, being first reported in Illinois from sandy prairies and barrens.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CASS CO. Beardstown, *McDonald*, Sept., 1901. HENDERSON CO. Oquawka, *Patterson*, Sept., 1872. MASON CO. Without locality, *Wolf*. WABASH CO. Hanging Rock, *Schneck*, Oct., 1900; Mt. Carmel, *Schneck*, Oct., 1876.

49. ERAGROSTIS Beauv.

These grasses vary considerably in habit. There are both annual and perennial species. The panicles are composed of 2- to many-flowered spikelets. The glumes are keeled and shorter than the florets. The leaves are generally flat and narrow; the ligule is composed of a row of hairs. Owing to the great variation in the number of florets in a spikelet, the same species may present a very different appearance under different conditions and at different seasons of the year. *Eragrostis hypnoides* is dioecious; the lemmas of the pistillate flowers are always slightly narrower and more pointed than those of the staminate. The lemmas of many species fall with the grain when it is ripe, leaving the paleas attached to the rachilla.

a. Culms erect or ascending, not creeping along the ground and rooting at the nodes.
  b. Spikelets usually less than 5-flowered, 2 to 3 mm. long.

c. Spikelets on capillary pedicels which are at least 5 mm. long; plants branched at the base; length and breadth of the panicle approximately equal. *E. capillaris*

cc. Spikelets borne on stiff pedicels which are less than 5 mm. long; plants branched from above the base; panicles much longer than broad. *E. frankii*

bb. Spikelets usually more than 5-flowered, 5 to 16 mm. long.

c. Plants usually less than 18 inches tall, in dense tufts, often spreading; panicles small, densely flowered, with short branches; annuals, usually gray-green in color.

d. Spikelets 1.5 mm. or less in width, without glandular spots; throat of sheath and bases of lower panicle branches densely pubescent. *E. pilosa*

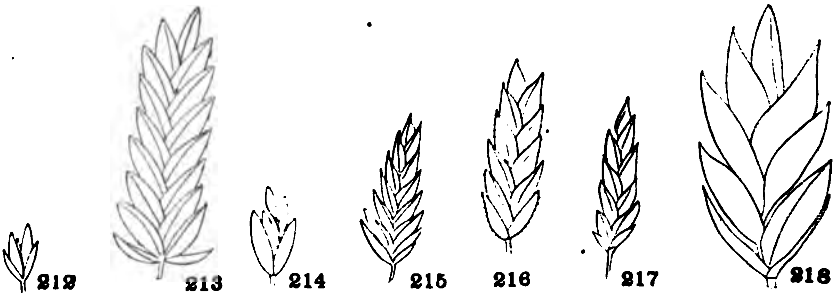
dd. Spikelets 2 to 3 mm. wide, the keels of the glumes and lemmas and their pedicels with glandular spots; throat of sheath and bases of lower panicle branches not densely pubescent. *E. cilianensis*

cc. Plants usually more than 18 inches tall; panicles large, loosely flowered, purplish or yellowish; perennials.

d. Panicles purplish, a conspicuous tuft of hairs in the axils; lemmas 1.5 to 2 mm. long. *E. pectinacea*

dd. Panicles yellowish, often tinged with purple; axils naked; lemmas 2.5 to 3 mm. long. *E. trichodes*

aa. Culms creeping along the ground, rooting at the nodes; an annual of wet places. *E. hypnoides*



Figs. 212–218.—Spikelets: 212, *E. capillaris;* 213, *E. cilianensis;* 214, *E. frankii;* 215, *E. hypnoides;* 216, *E. pectinacea;* 217, *E. pilosa;* 218, *E. trichodes*

Eragrostis capillaris (L.) Nees

(Fig. 212)

Lapham '57, 581; Patterson '76, 51; Flagg '78, 281; Brendel '87, 64; Huett '97, 130.

Culms branched at the base, simple above, growing in tufts, 6 to 24 inches tall; sheaths smooth or sparsely pubescent; blades 3 to 10 inches long, 2 to 4 mm. wide, with a few hairs near the base; ligule a fringe of hairs, 1 to 2 mm. long; panicle usually nearly the whole length of the plant, always more than half, diffuse, the branches capillary, the pedicels mostly over 5 mm. long; spikelets 2- to 4-flowered, 2 to 3 mm. long.

This delicate species is native to Illinois. It resembles *E. frankii* more than any other species, but its panicle is always longer. It is found in dry sandy soil.

ILLINOIS SPECIMENS: Without locality, *Hall;* Spoon river, *Brendel* in 1859; Carson, *Eggert* in 1878. CHRISTIAN CO. Taylorville, *Andrews.* DU PAGE CO. Hinsdale, *Smith,* Sept., 1902. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon.* HANCOCK CO. Augusta, *Mead* in 1843. LAKE CO. Channel lake, *Haynes,* Aug., 1905. MACOUPIN CO. Carlinville, *Robertson,* Aug., 1882. PEORIA CO. Peoria, *McDonald,* Aug., 1892 and 1897; Peoria, *Brendel.* POPE CO. Herod, *Clinton,* July, 1898. ST. CLAIR CO. Mascoutah, *Welsch.* WABASH CO. Without locality, *Shearer;* Hanging Rock, *Schneck,* Sept., 1904; Mt. Carmel, *Schneck,* July, 1900.

Eragrostis cilianensis (All.) Link

Candy Grass. Stink Grass. Snake Grass (Fig. 213)

Eragrostis megastachya, Lapham '57, 547, 580. *E. poaeoides* var. *megastachya,* Babcock '73, 97; Patterson '76, 51; Flagg '78, 281; Higley and Raddin '91, 144. *Eragrostis major,* Huett '97, 130.

Culms 8 to 24 inches tall, usually spreading; sheaths shorter than the internodes, hairy at the throat; blades rough on the upper surface, 2 to 6 inches long; ligule a ring of hairs 1 to 3 mm. long; panicle dark gray-green, 2 to 6 inches long; spikelets 5 to 25 mm. long, 10- to 40-flowered; lemmas 2 to 2.5 mm. long; pedicels and keels of the glumes and lemmas glandular.

This grass is abundant everywhere in the state. It was introduced into the United States from Europe and is a well-known weed in gardens and waste places. It is easily controlled by thoro cultivation. The glands on the spikelets give out a strong and rather disagreeable odor.

COOK CO. Hyde Park, Chicago, *A. Chase* 1182; Rogers Park, *Johnson,* July, 1890; Chicago, *A. Chase,* Aug., 1899; Chicago, *Babcock,* Aug., 1874; Evanston, *Johnson,* Sept., 1888; Chicago, *Lansing* in 1897; Hyde Park, Chicago, *Lansing,* July, 1898. CHAMPAIGN CO. Without locality, *Percival,* Nov., 1876; Urbana, *Seymour,* June, 1880; Urbana, *Mosher,* Sept., 1913; Urbana, *Clinton,* Aug., 1895; Urbana, *Gibbs,* Sept., 1898; Champaign, *Mosher,* Aug., 1913. CHRISTIAN CO. Taylorville, *De Motte;* Taylorville, *Andrews.* DU PAGE CO. Hinsdale, *Smith,* Aug., 1902. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon.* HENDERSON CO. Oquawka, *Patterson* in 1871. KANE CO. Elgin, *Sherff* 1790. KANKAKEE CO. Kankakee, *Reecher,* Aug., 1899. LAKE CO. Channel lake, *Haynes,* Aug., 1905. MCHENRY CO. Algonquin, *Nason,* Aug., 1878; Ringwood, *Vasey.* MASON CO. Havana, *Burrill* and *Clinton,* June, 1894. PEORIA CO. Peoria, *McDonald,* Aug., 1904; Peoria, *Brendel;* Peoria, *V. H. Chase* 125. ST. CLAIR CO. Mascoutah, *Welsch.* WABASH CO. Without locality, *Shearer;* Mt. Carmel, *Schneck,* Oct., 1902.

Eragrostis frankii (Fisch. Mey. and Lall.) Steud.

(Fig. 214)

Lapham '57, 547, 580; Babcock '73, 97; Patterson '76, 51; Flagg '78, 281; Brendel '87, 64; Higley and Raddin '91, 144; Huett '97, 130; Sherff '13, 595.

Culms sometimes erect, but often spreading and forming a dense tuft, 6 to 16 inches tall; sheaths smooth; ligule a ring of short hairs with longer hairs at the margin; blades 2 to 5 inches long, 2 to 4 mm. wide, rough on the upper surface; panicle spreading, usually dark gray-green, the pedicels less than 5 mm. long, giving the panicle a denser appearance than in *E. capillaris;* spikelets 3- to 5-flowered, 2 to 3 mm. long, lemmas about 1.5 mm. long.

These plants are generally much smaller than those of *E. capillaris,* which it resembles considerably. It is also a darker green with denser panicles and grows in rather damp places, altho it is found along roadsides and various waste places.

ILLINOIS SPECIMENS: Without locality, *Vasey;* Cahokia, *Eggert,* Sept., 1878. CHAMPAIGN CO. Mahomet, *Burrill* and *Seymour,* Aug., 1880; Urbana, *Clinton,* Sept., 1895; Urbana, *Gibbs,* Sept., 1898. COOK CO. Grand Crossing, *A. Chase,* Sept., 1902; Evanston, *Johnson,* Sept., 1886. FULTON CO. Canton, *Wolf.* MCHENRY CO. Ringwood, *Vasey;* Algonquin, *Nason,* Aug., 1879. MACON CO. Decatur, *Clokey,* Aug., 1897. MACOUPIN CO. Carlinville, *Robertson,* Aug., 1880. MENARD CO. Without locality, *Hall.* PEORIA CO. Peoria, *McDonald,* Aug., 1897 and 1899; Peoria, *Brendel.* ST. CLAIR CO. Without locality, *Brendel;* Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase* 1260. WABASH CO. Without locality, *Shearer,* July, 1900; Mt. Carmel, *Schneck,* Oct., 1900. WINNEBAGO CO. Fountaindale, *M. S. Bebb.*

Eragrostis hypnoides (Lam.) B. S. P.

Creeping Eragrostis (Fig. 215)

Poa reptans, Michaux '03, 69. *Eragrostis reptans,* Lapham '57, 547, 580 (Plate 2, Fig. 13); Babcock '73, 97; Patterson '76, 51; Brendel '87, 64; Higley and Raddin '91, 144; Huett '97, 130. *Eragrostis hypnoides,* Gleason '12, 44; Sherff '13, 595.

Culms creeping along the ground and rooting at the nodes, 8 to 20 inches long; sheaths hairy at the throat; blades 1 to 2 inches long, 1 to 2 mm. wide, rough above; spikelets smooth or sparsely pubescent, 10- to 35-flowered, 5 to 15 mm. long, lemmas about 2.5 mm. long, the nerves very prominent.

This grass is found in wet places, generally along the margins of ditches, rivers, lakes, etc. It prefers sandy soil.

ILLINOIS SPECIMENS: Northern Illinois, *M. S. Bebb* in 1858; Eagle I., Mississippi bottoms, *Patterson* in 1871; Cahokia Mound, *Ward,* Aug., 1878. CHAMPAIGN CO. Urbana, *Waite,* Sept., 1884; Urbana, *Clinton,* Sept., 1895. CHRISTIAN CO. Taylorville, *Andrews.* COOK CO. Palos Park, *Umbach,* Sept., 1909. DU PAGE CO. Naperville, *Umbach,* Sept., 1899. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon,* Aug., 1908. HENDERSON CO. Banks of Mississippi near Oquawka, *Patterson,* Sept., 1871. KANE CO. Elgin, banks of Fox river, *Umbach,* July, 1895. LAKE CO. Skokie marsh near Waukegan, *Sherff,* Aug., 1911; Channel lake, *Haynes,* Aug., 1905. MCHENRY CO. Ringwood, *Vasey.* MADISON CO. Without locality, *Eggert,* Sept., 1886. PEORIA CO. Peoria, *McDonald,* Sept., 1900; Peoria, *Brendel.* POPE CO. Herod, *Clinton,* July, 1898. ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. Near Wady Petra, *V. H. Chase,* Aug., 1897. WABASH CO. Without locality, *Shearer,* Aug., 1899; Banks of Wabash at Hurd's Ferry, *Schneck,* Oct., 1888; banks of Wabash river at Grand Rapids, *Schneck,* Oct., 1880; Mt. Carmel, *Schneck,* Oct., 1900; Mt. Carmel, *Waite,* Aug., 1887.

Eragrostis pectinacea (Michx.) Nees
Purple Eragrostis (Fig. 216)

Poa pectinacea, Michaux '03, 69; Engelmann '44, 104. *Eragrostis spectabilis*, Lapham '57, 547, 581; Patterson '76, 51. *Eragrostis pectinacea*, Flagg '78, 282; Brendel '87, 64; Higley and Raddin '91, 144; Huett '97, 130; Gleason '07, 182; Gleason '10, 149.

Culms 1 to 3 feet tall, simple; sheaths usually sparsely pubescent but often smooth, bearded at the throat; blades 4 to 12 inches long, 4 to 8 mm. wide, rough above, pubescent near the base; panicles purple, large and spreading, with a conspicuous tuft of hairs in the axils, sometimes partially included in the upper sheaths; spikelets on long, stiff pedicels, 5- to 15-flowered, 3 to 8 mm. long; lemmas 1.5 to 2 mm. long.

This grass is very conspicuous in the autumn, with its large purple panicles. These often break off and blow before the wind like tumbleweeds. It prefers dry soil.

ILLINOIS SPECIMENS: Without locality, *Hall;* without locality, *Vasey.* CASS CO. Chandlerville, *Seymour,* Aug., 1886. CHAMPAIGN CO. Urbana, *Clinton,* Aug., 1895; Urbana, *Mosher,* Oct., 1912. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon* 413. HENDERSON CO. Oquawka, *Patterson* in 1872. MACOUPIN CO. Carlinville, *Robertson.* MASON CO. Sand hills, *Wolf;* Manito, *Wilcox,* July, 1902. MENARD CO. Athens, *Hall,* Sept., 1861 and 1864. OGLE CO. Oregon, *Waite,* Aug., 1884. PEORIA CO. Peoria, *McDonald,* Aug., 1887, 1900 and 1905; Peoria, *Brendel;* Princeville, *V. H. Chase* 757. UNION CO. Cobden, *Seymour,* Oct., 1881. WABASH CO. Without locality, *Schneck,* Aug., 1880; without locality, *Shearer;* Mt. Carmel, *Schneck,* Aug., 1880.

Eragrostis pilosa (L.) Beauv.
(Fig. 217)

Lapham '57, 547, 580; Babcock '73, 97; Patterson '76, 51; Flagg '78, 281; Higley and Raddin '91, 144; Huett '97, 130.

Culms erect, branched at the base, 6 to 18 inches tall; sheaths with long hairs at the throat, otherwise smooth; blades 1 to 5 inches long, 2 to 3 mm. wide; panicle open but rather narrow, usually a tuft of long hairs at the base of the lower branches; spikelets narrow, 5- to 18-flowered, 4 to 9 mm. long; lower lemmas 1.5 mm. long.

This is the commonest species of Eragrostis in Illinois; it is found in waste places everywhere.

ILLINOIS SPECIMENS: Without locality, *Vasey.* CASS CO. Chandlerville, *Hall,* Aug., 1880. CHAMPAIGN CO. Urbana, *Clinton,* Sept., 1895; Urbana, *Mosher,* Oct., 1913; Champaign, *Clinton,* Sept., 1899; Champaign, *Seymour,* July, 1880. COOK CO. Riverside, *Moffatt,* Aug., 1891; Evanston, *Johnston,* Aug., 1889; Ravenswood, Chicago, *Gates,* Aug., 1906; Hyde Park, Chicago, *A. Chase,* Aug., 1899; Chicago, *Babcock,* Sept., 1874. JO DAVIESS CO. Without locality, *Pepoon* 927. KANE CO. Elgin, *Sherff* 1791. KANKAKEE CO. Kankakee, *De Selm,* Aug., 1913. MCHENRY CO. Ringwood, *Vasey;* Algonquin, *Nason,* Aug., 1879. MACON CO. Decatur, *Clokey,* Aug., 1897. MACOUPIN CO. Carlinville, *Robertson,* July, 1879. MENARD CO. Athens, *Hall* in 1862 and 1864. PEORIA CO. Peoria, *Brendel* in 1859; Peoria, *McDonald,* Aug., 1887. PIATT CO. Deland, *Seymour,* Sept., 1889. ROCK ISLAND CO. Rock Island, *McDonald,* July, 1893. ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. *V. H. Chase* 124 and 1544. UNION CO. Cobden, *Seymour,* tuft, 6 to 16 inches tall; sheaths smooth; ligule a ring of short hairs with longer hairs at the margin; blades 2 to 5 inches long, 2 to 4 mm. wide, rough on the upper surface; panicle spreading, usually dark gray-green, the pedicels less than 5 mm. long, giving the panicle a denser appearance than in *E. capillaris;* spikelets 3- to 5-flowered, 2 to 3 mm. long, lemmas about 1.5 mm. long.

These plants are generally much smaller than those of *E. capillaris,* which it resembles considerably. It is also a darker green with denser panicles and grows in rather damp places, altho it is found along roadsides and various waste places.

ILLINOIS SPECIMENS: Without locality, *Vasey;* Cahokia, *Eggert,* Sept., 1878. CHAMPAIGN CO. Mahomet, *Burrill* and *Seymour,* Aug., 1880; Urbana, *Clinton,* Sept., 1895; Urbana, *Gibbs,* Sept., 1898. COOK CO. Grand Crossing, *A. Chase,* Sept., 1902; Evanston, *Johnson,* Sept., 1886. FULTON CO. Canton, *Wolf.* MCHENRY CO. Ringwood, *Vasey;* Algonquin, *Nason,* Aug., 1879. MACON CO. Decatur, *Clokey,* Aug., 1897. MACOUPIN CO. Carlinville, *Robertson,* Aug., 1880. MENARD CO. Without locality, *Hall.* PEORIA CO. Peoria, *McDonald,* Aug., 1897 and 1899; Peoria, *Brendel.* ST. CLAIR CO. Without locality, *Brendel;* Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase* 1260. WABASH CO. Without locality, *Shearer,* July, 1900; Mt. Carmel, *Schneck,* Oct., 1900. WINNEBAGO CO. Fountaindale, *M. S. Bebb.*

Eragrostis hypnoides (Lam.) B. S. P.

Creeping Eragrostis (Fig. 215)

Poa reptans, Michaux '03, 69. *Eragrostis reptans,* Lapham '57, 547, 580 (Plate 2, Fig. 13); Babcock '73, 97; Patterson '76, 51; Brendel '87, 64; Higley and Raddin '91, 144; Huett '97, 130. *Eragrostis hypnoides,* Gleason '12, 44; Sherff '13, 595.

Culms creeping along the ground and rooting at the nodes, 8 to 20 inches long; sheaths hairy at the throat; blades 1 to 2 inches long, 1 to 2 mm. wide, rough above; spikelets smooth or sparsely pubescent, 10- to 35-flowered, 5 to 15 mm. long, lemmas about 2.5 mm. long, the nerves very prominent.

This grass is found in wet places, generally along the margins of ditches, rivers, lakes, etc. It prefers sandy soil.

ILLINOIS SPECIMENS: Northern Illinois, *M. S. Bebb* in 1858; Eagle I., Mississippi bottoms, *Patterson* in 1871; Cahokia Mound, *Ward,* Aug., 1878. CHAMPAIGN CO. Urbana, *Waite,* Sept., 1884; Urbana, *Clinton,* Sept., 1895. CHRISTIAN CO. Taylorville, *Andrews.* COOK CO. Palos Park, *Umbach,* Sept., 1909. DU PAGE CO. Naperville, *Umbach,* Sept., 1899. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon,* Aug., 1908. HENDERSON CO. Banks of Mississippi near Oquawka, *Patterson,* Sept., 1871. KANE CO. Elgin, banks of Fox river, *Umbach,* July, 1895. LAKE CO. Skokie marsh near Waukegan, *Sherff,* Aug., 1911; Channel lake, *Haynes,* Aug., 1905. MCHENRY CO. Ringwood, *Vasey.* MADISON CO. Without locality, *Eggert,* Sept., 1886. PEORIA CO. Peoria, *McDonald,* Sept., 1900; Peoria, *Brendel.* POPE CO. Herod, *Clinton,* July, 1898. ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. Near Wady Petra, *V. H. Chase,* Aug., 1897. WABASH CO. Without locality, *Shearer,* Aug., 1899; Banks of Wabash at Hurd's Ferry, *Schneck,* Oct., 1888; banks of Wabash river at Grand Rapids, *Schneck,* Oct., 1880; Mt. Carmel, *Schneck,* Oct., 1900; Mt. Carmel, *Waite,* Aug., 1887.

Eragrostis pectinacea (Michx.) Nees
Purple Eragrostis (Fig. 216)

Poa pectinacea, Michaux '03, 69; Engelmann '44, 104. *Eragrostis spectabilis*, Lapham '57, 547, 581; Patterson '76, 51. *Eragrostis pectinacea*, Flagg '78, 282; Brendel '87, 64; Higley and Raddin '91, 144; Huett '97, 130; Gleason '07, 182; Gleason '10, 149.

Culms 1 to 3 feet tall, simple; sheaths usually sparsely pubescent but often smooth, bearded at the throat; blades 4 to 12 inches long, 4 to 8 mm. wide, rough above, pubescent near the base; panicles purple, large and spreading, with a conspicuous tuft of hairs in the axils, sometimes partially included in the upper sheaths; spikelets on long, stiff pedicels, 5- to 15-flowered, 3 to 8 mm. long; lemmas 1.5 to 2 mm. long.

This grass is very conspicuous in the autumn, with its large purple panicles. These often break off and blow before the wind like tumbleweeds. It prefers dry soil.

ILLINOIS SPECIMENS: Without locality, *Hall;* without locality, *Vasey.* CASS CO. Chandlerville, *Seymour,* Aug., 1886. CHAMPAIGN CO. Urbana, *Clinton,* Aug., 1895; Urbana, *Mosher,* Oct., 1912. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon* 413. HENDERSON CO. Oquawka, *Patterson* in 1872. MACOUPIN CO. Carlinville, *Robertson.* MASON CO. Sand hills, *Wolf;* Manito, *Wilcox,* July, 1902. MENARD CO. Athens, *Hall,* Sept., 1861 and 1864. OGLE CO. Oregon, *Waite,* Aug., 1884. PEORIA CO. Peoria, *McDonald,* Aug., 1887, 1900 and 1905; Peoria, *Brendel;* Princeville, *V. H. Chase* 757. UNION CO. Cobden, *Seymour,* Oct., 1881. WABASH CO. Without locality, *Schneck,* Aug., 1880; without locality, *Shearer;* Mt. Carmel, *Schneck,* Aug., 1880.

Eragrostis pilosa (L.) Beauv.
(Fig. 217)

Lapham '57, 547, 580; Babcock '73, 97; Patterson '76, 51; Flagg '78, 281; Higley and Raddin '91, 144; Huett '97, 130.

Culms erect, branched at the base, 6 to 18 inches tall; sheaths with long hairs at the throat, otherwise smooth; blades 1 to 5 inches long, 2 to 3 mm. wide; panicle open but rather narrow, usually a tuft of long hairs at the base of the lower branches; spikelets narrow, 5- to 18-flowered, 4 to 9 mm. long; lower lemmas 1.5 mm. long.

This is the commonest species of Eragrostis in Illinois; it is found in waste places everywhere.

ILLINOIS SPECIMENS: Without locality, *Vasey.* CASS CO. Chandlerville, *Hall,* Aug., 1880. CHAMPAIGN CO. Urbana, *Clinton,* Sept., 1895; Urbana, *Mosher,* Oct., 1913; Champaign, *Clinton,* Sept., 1899; Champaign, *Seymour,* July, 1880. COOK CO. Riverside, *Moffatt,* Aug., 1891; Evanston, *Johnston,* Aug., 1889; Ravenswood, Chicago, *Gates,* Aug., 1906; Hyde Park, Chicago, *A. Chase,* Aug., 1899; Chicago, *Babcock,* Sept., 1874. JO DAVIESS CO. Without locality, *Pepoon* 927. KANE CO. Elgin, *Sherff* 1791. KANKAKEE CO. Kankakee, *De Selm,* Aug., 1913. MCHENRY CO. Ringwood, *Vasey;* Algonquin, *Nason,* Aug., 1879. MACON CO. Decatur, *Clokey,* Aug., 1897. MACOUPIN CO. Carlinville, *Robertson,* July, 1879. MENARD CO. Athens, *Hall* in 1862 and 1864. PEORIA CO. Peoria, *Brendel* in 1859; Peoria, *McDonald,* Aug., 1887. PIATT CO. Deland, *Seymour,* Sept., 1889. ROCK ISLAND CO. Rock Island, *McDonald,* July, 1893. ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. *V. H. Chase* 124 and 1544. UNION CO. Cobden, *Seymour,* Aug., 1880; Anna, *Seymour,* Aug., 1880. WABASH CO. Without locality, *Shearer,* Aug., 1897; Hurd's Ferry, *Schneck,* July, 1871; Mt. Carmel, *Schneck,* Sept., 1879; Bellmont, *Schneck,* Aug., 1889.

Eragrostis trichodes (Nutt.) Nash
(Fig. 218)

Eragrostis tenuis, Lapham '57, 547, 581; Patterson '76, 51; Flagg '78, 281; Brendel '87, 88; Higley and Raddin '91, 144; McDonald '00, 103. *Eragrostis trichodes,* **Gleason '07, 182; Gleason '10, 149.**

Culms erect, 2 to 5 feet tall; sheaths long, overlapping one another, smooth, hairy at the throat; blades 4 to 30 inches long, 2 to 6 mm. wide, slightly rough on the upper surface, stiff and pointed at the tip; panicles much longer than wide, spreading and open, the spikelets borne on long, hair-like pedicels; spikelets usually yellowish, 3- to 10-flowered, lemmas 2.5 to 3 mm. long.

This species is found abundantly in the dry, sandy areas thruout the state.

ILLINOIS SPECIMENS: Without locality, southern Illinois, *Brendel* in 1861; Carson, *Eggert,* May, 1878. CASS CO. Beardstown, *McDonald,* Aug., 1892; Chandlerville, *Seymour,* Aug., 1886. CHRISTIAN CO. Taylorville, *Andrews.* HENDERSON CO. Without locality, *Patterson;* near Oquawka, *Patterson,* Sept., 1871. LA SALLE CO. Starved Rock, *Waite,* Aug., 1884. MADISON CO. Without locality, *Eggert,* Aug., 1878. MASON CO. Without locality, *Wolf;* Havana, *Trelease* in 1914. MENARD CO. Athens, *Hall* in 1861.

Engelmann ('44, p. 104) cites *Poa hirsuta,* now *E. hirsuta,* as occurring in the state, but no specimens of this have been seen, and it is doubtful whether the species was correctly determined. Higley and Raddin ('91, p. 144) cite *Eragrostis minor,* a European species but sparingly introduced into this country. Out of many specimens labeled *E. minor* in collections which were examined, not one proved to be correctly determined; all were small specimens of *E. cilianensis.*

50. MELICA L.
Melic Grass

These grasses are perennials with paniculate inflorescence. The spikelets are large, from 7 to 12 mm. long. The glumes and lemmas are thin and papery, with a broad, transparent margin which is considerably roughened. The spikelets are 2- to several-flowered, the upper sterile lemmas reduced to club-shaped or hood-like rudiments (Fig. 222). The leaf sheaths are closed and the blades are long and narrow with long membranous ligules.

Glumes nearly equal in length and almost or quite as long as the 2-flowered spikelet; panicle simple or but little branched. *M. mutica*

Glumes unequal and considerably shorter than the spikelet, which is usually 3-flowered; panicle compound, the branches spreading. *M. nitens*

Melica mutica Walt.

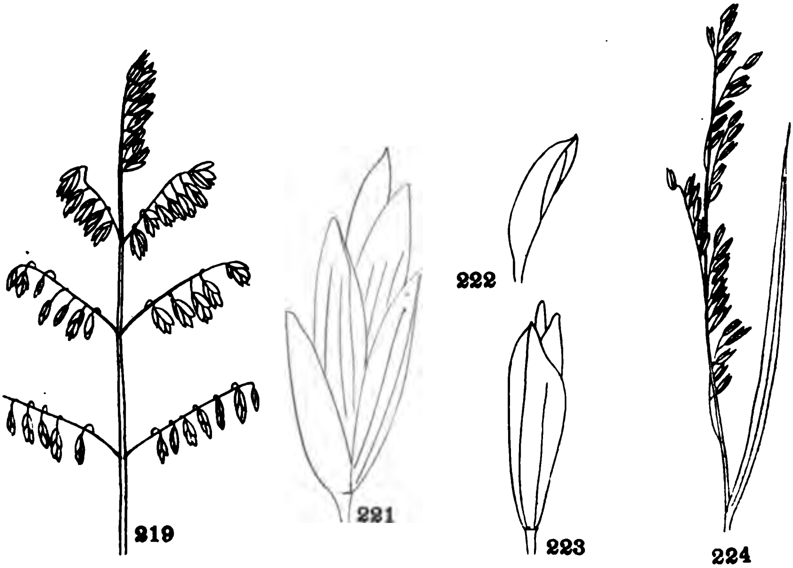
Narrow Melic Grass (Figs. 223 and 224)

Melica speciosa, **Engelmann '44, 103.** ***M. mutica,*** **Lapham '57, 576; Flagg '78, 281; Brendel '87, 63; Huett '97, 130.**

Culms erect, 2 to 3 feet tall, slender; sheaths usually overlapping; blades rough, 4 to 8 inches long, 2 to 10 mm. wide; panicles narrow with short, ascending branches, or reduced to a raceme; spikelets 7 to 10 mm. long, rough, nodding; lemmas 6 to 8 mm. long; both glumes and lemmas with thin, whitish margins; glumes nearly equal, almost or quite as long as the floret.

This species is usually found in open woods.

HENDERSON CO. Oquawka, *Patterson.* MACOUPIN CO. Without locality, *Robertson.* MARION CO. Without locality, *Lapham.* PEORIA CO. Peoria, *Brendel.*



Figs. 219–224.—219, *M. nitens,* inflorescence; 221, *M. nitens,* spikelet; 222, *M. nitens,* sterile lemma; 223, *M. mutica,* spikelet; 224, *M. mutica,* inflorescence

Melica nitens Nutt.

Tall Melic Grass (Figs. 219, 221, and 222)

Culms 2.5 to 4 feet tall, rather stout; sheaths smooth, blades 4 to 8 inches long, 4 to 8 mm. wide; panicle usually spreading, with numerous spikelets; spikelets 10 to 12 mm. long, usually 3-flowered; lemmas 7 to 9 mm. long, rough with thin, transparent border; glumes unequal and the first glume shorter than the second, both considerably shorter than the spikelet.

This species is much more abundant than *M. mutica* in Illinois. It is probable that the two species have been confused. *M. mutica* is a smaller and more delicate plant, but the species are most readily distinguished by the spikelet characters.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHRISTIAN CO. Taylorville, *Andrews*. COOK CO. Lemont, *Hill*, June, 1899. JOHNSON CO. Tunnel Hill, *Schneck*, May, 1902. KANKAKEE CO. Kankakee, *Hill* 27 in 1872. MACON CO. Decatur, *Clokey*, May, 1899. OGLE CO. Oregon, *Waite*, June, 1885. PEORIA CO. Peoria, *McDonald*, June, 1885, and 1894; Peoria, *Brendel*. ST. CLAIR CO. Mascoutah, *Welsch*. SANGAMON CO. Springfield, *M. S. Bebb*. STARK CO. Near Wady Petra, *V. H. Chase* 1092. VERMILION CO. Muncie, *Mosher*, June, 1914. WABASH CO. Without locality, *Schneck*, June, 1895 and 1901; without locality, *Shearer*, June, 1895. WILL CO. Joliet, *Hill* 11 in 1907.

51. DIARINA Raf.

This genus is easily distinguished by its large spikelets with large, hardened, shiny lemmas. The plants are perennial with long, creeping rootstocks and simple culms. The leaves are stiff, rather broad, and nearly as long as the culm. The ligule is membranous and very short. The spikelets are 3- to 5-flowered, but the upper florets bear no seed.

Diarina festucoides Raf.

(Figs. 225 and 226)

Diarrhena americana, Engelmann '44, 108. *Diarrhena diandra*, Lapham '57, 546, 574 (Plate 2, Fig. 8). *Diarrhena americana*, Babcock '73, 97; Patterson '76, 50; Flagg '78, 281; Brendel '81, 63; Higley and Raddin '91, 144; Huett '97, 130.

Culms erect, 3 to 4 feet tall; sheaths smooth; blades usually roughened, 8 to 30 inches long, 10 to 18 mm. wide; panicles narrow, few-flowered, 4 to 10 inches long; spikelets 10 to 16 mm. long, lemmas usually brown.

This species is found in rich, damp woods.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Urbana, *Clinton*, Oct., 1895. CHRISTIAN CO. Taylorville, *Andrews*. FULTON CO. Without locality, *Pepoon;* Canton, *Wolf*. MENARD CO. Without locality, *Hall*, Aug., 1868. JO DAVIESS CO. Without locality, *Pepoon*. PEORIA CO. Peoria, *Brendel*. ST CLAIR CO. Mascoutah, *Welsch*. STARK CO. Along Spoon river, *V. H. Chase* 1539. TAZEWELL CO. Without locality, *McDonald*, July, 1889. VERMILION CO. Muncie, *Mosher*, May, 1814. WABASH CO. Banks of the Wabash river, *Schneck*, July, 1904; Mt. Carmel, *Schneck*, Sept., 1880; Mt. Carmel, *Patterson*, Sept., 1877.

52. UNIOLA L.

Spike Grass

This typically southern genus is represented by a single species in Illinois. The plants are very striking, with broad leaves and an open, drooping panicle of large flattened spikelets. The spikelets are 6- to 12-flowered, 1 to 4 of the lower lemmas being empty. This species is found in shaded woods and thickets. It is most distinctive and perhaps the most beautiful grass found in Illinois.

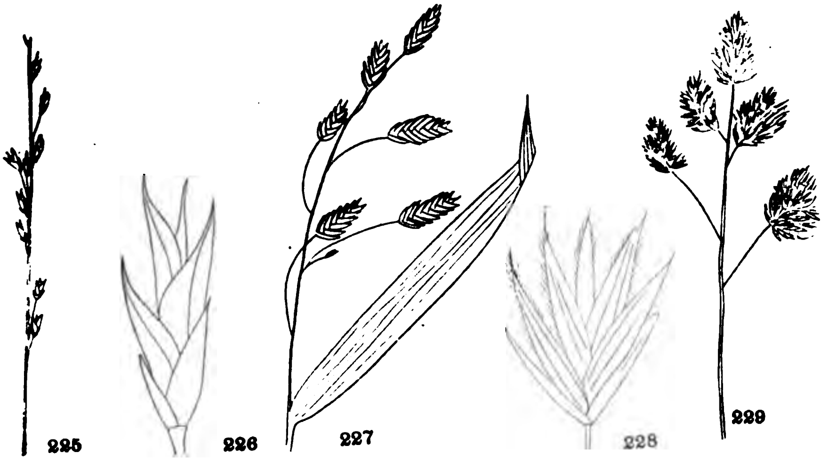
Uniola latifolia Michx.

Broad-leaved Spike Grass (Fig. 227)

Lapham '57, 547, 583 (Plate 3, Fig. 3); Patterson '76, 51; Flagg '78, 282; Brendel '87, 88.

Culms erect, smooth, 2 to 5 feet tall; sheaths smooth, shorter than the internodes; ligule membranous, the edges erose, about 1 mm. long; blades 4 to 10 inches long, 5 to 20 mm. wide, sharply pointed at the apex, the edges rough and often ciliate near the base; panicle branches slender, drooping with the weight of the large spikelets; spikelets 15 to 30 mm. long, the lemmas 9 to 12 mm. long, keeled, ciliate on the keel.

ILLINOIS SPECIMENS: Without locality, southern Illinois, *Vasey*. CHRISTIAN CO. Taylorville, *Andrews*. JACKSON CO. Makanda, *Seymour*, Aug., 1880. KANKAKEE CO. Kankakee, *Hill*, June, 1870. MACON CO. Decatur, *Clokey*, Aug., 1896. MACOUPIN CO. Carlinville, *Robertson*, Aug., 1880. MENARD CO. Athens, *Hall* in 1868. POPE CO. Herod, *Clinton*, July, 1898. PULASKI CO. Mound City, *Brendel*. ST. CLAIR CO. Without locality, *Brendel*, Aug., 1850; Mascoutah, *Welsch*. UNION CO. Cobden, *Seymour* 37. WABASH CO. Without locality, *Shearer;* Old Palmyra, *Schneck*, Aug., 1904; Hanging Rock, *Schneck*, Oct., 1900; Mt. Carmel, *Schneck*, July, 1879.



Figs. 225–229.—225, *D. diandra*, inflorescence; 226, *D. diandra*, spikelet; 227, *U. latifolia*, inflorescence; 228, *D. glomerata*, spikelet; 229, *D. glomerata*, inflorescence

53. DACTYLIS L.

This European genus is represented in Illinois by a single species. *D. glomerata*. It is distinguished by the peculiar form of the panicle which is composed of one-sided clusters of densely crowded spikelets at the ends of the stiff, naked branches. The branches spread at flowering, but contract at maturity. The spikelets are 2- to 5-flowered, flattened; the lemmas are ciliate and awn-pointed. The leaves are long and narrow, the ligule thin and membranous, 1 to 5 mm. long.

Dactylis glomerata L.

Orchard Grass. Cock's-foot (Figs. 228 and 229)

Lapham '57, 546, 575 (Plate 2, Fig. 9); Babcock '73, 97; Patterson '76, 50; Flagg '78, 281; Higley and Raddin '91, 144; Huett '97, 130.

Culms rough, 2 to 4 feet tall, in large tufts; sheaths rough, somewhat flattened and keeled; blades flat, usually rough on both surfaces, 3 to 9 inches long, 1 to 6 mm. wide; panicles 3 to 6 inches long, branches stiff, the spikelets clustered at the ends; spikelets 3- to 4-flowered; lemmas 4 to 6 mm. long, rough, ciliate on the keel.

This grass is cultivated extensively as a forage grass. It grows well in shady places. It is a perennial grass which soon becomes permanently established, being found in waste places thruout the state.

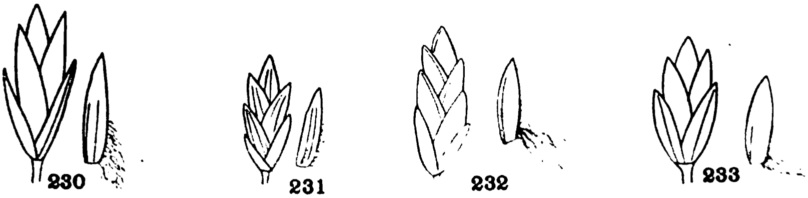
CHAMPAIGN CO. Urbana, *Burrill*, June, 1878; Urbana, *Clinton*, June, 1897. CHRISTIAN CO. Taylorville, *Andrews*. COOK CO. Evanston, *Shipman*; Winnetka, *Sherff* 1924. DU PAGE CO. Naperville, *Umbach*, May, 1896. FULTON CO. Canton, *Wolf*. JO DAVIESS CO. Without locality, *Pepoon*. KANKAKEE CO. Kankakee, *Reecher*, July, 1908; Kankakee, *De Selm*, June, 1913. LAKE CO. Ravinia, *Gates* 1698.1. MACON CO. Decatur, *Clokey*, May, 1899. MACOUPIN CO. Carlinville, *Robertson*, May, 1883. PEORIA CO. Peoria, *McDonald*, June, 1896; Peoria, *Brendel*. ST. CLAIR CO. Without locality, *Brendel*; Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase* 57. WABASH CO. Mt. Carmel, *Schneck*, July, 1888. WILL CO. Joliet, *Skeels*, June, 1904.

54. POA L.

This genus includes a large number of species in the cooler parts of the country. The plants are mostly perennials, but two of our common species are annuals. The spikelets are 2- to 6-flowered, usually in open panicles like those of the well-known Kentucky blue grass. Nearly all our species have a tuft of cobwebby hairs at the base of the lemma. The leaves are narrow, and have a boat-shaped tip; the ligules are membranous, sometimes 4 or 5 mm. long.

a. Culms less than a foot tall, low, tufted, winter annuals.
b. Lemmas webbed at the base, apparently 3-nerved, the intermediate nerves obscure. ***P. chapmaniana***
bb. Lemmas not webbed at the base, distinctly 5-nerved, the nerves all prominent. ***P. annua***
aa. Culms normally much over a foot tall; perennial grasses.
b. Lemmas with all the nerves smooth. ***P. debilis***
bb. Lemmas with some of the nerves pubescent.
c. Intermediate nerves of the lemma prominent.
d. Midnerve pubescent for its whole length or nearly so; the second glume two-thirds the length of the spikelet. ***P. sylvestris***
dd. Midnerve never pubescent for its whole length; second glume never two-thirds the length of the spikelet.
e. Plants with long, creeping rootstocks; spikelets usually less than 5 mm. long; panicle branches spikelet-bearing below the middle. ***P. pratensis***
ee. Plants without rootstocks; spikelets 5 or 6 mm. long; panicle branches spikelet-bearing at the ends only. ***P. wolfii***
cc. Intermediate nerves of the lemma obscure.
f. Marginal nerves smooth; glumes narrow. ***P. alsodes***

ff. Marginal nerves pubescent; glumes broad.
  g. Stems strongly flattened; plants with long, creeping rootstocks; nerves of lemma with short pubescence near base; panicle usually narrow. *P. compressa*
  gg. Stems not flattened; plants without creeping rootstocks; nerves of lemma with long pubescence near base; panicle spreading. *P. palustris*



Figs. 230–233.—Spikelets; 230, *P. alsodes;* 231, *P. annua;* 232, *P. chapmaniana;* 233, *P. compressa*

Poa alsodes Gray

Grove Meadow Grass (Fig. 230)

Patterson '76, 51; Flagg '78, 281; Brendel '87, 88.

Culms 1 to 2 feet tall; sheaths smooth; the upper often inclosing the base of the panicle: blades 6 to 12 inches long, 2 to 5 mm. wide; panicle branches in whorls; spikelets 2- to 3-flowered, about 5 mm. long, the lemmas faintly nerved, the midnerve long pubescent near the base, the marginal and intermediate nerves smooth.

This species is apparently rare in Illinois. It grows in shady places in woods and groves.

CHAMPAIGN CO. Brownfield Woods near Urbana, *Pease,* May, 1909.

Poa annua L.

Annual Meadow Grass. Low Spear Grass (Fig. 231)

Lapham '57, 546, 578; Babcock '73, 97; Patterson '76, 51; Flagg '78, 281; Brendel '87, 64; Higley and Raddin, '91, 144.

Culms 2 to 12 inches tall, somewhat flattened, forming dense tufts, often decumbent, and rooting at the lower nodes; sheaths loose, smooth; blades 1 to 4 inches long, soft and smooth; panicle open; spikelets 3- to 6-flowered, 3 to 5 mm. long, usually 4 mm.; lemmas not webby at the base, distinctly 5-nerved, the nerves pubescent at the base.

This species was naturalized from Europe and is much less common than our native species, *P. chapmaniana,* with which it has been confused. It is a winter annual found in both cultivated and waste ground. It dies out in summer, leaving brown patches in lawns and fields where it has been growing.

CHRISTIAN CO. Taylorville, *Andrews.* CLARK CO. Cosey, *Price,* May, 1916. COOK CO. West Pullman, *Umbach,* May, 1898. DU PAGE CO. Naperville, *Umbach,* May, 1898; West Chicago, *Umbach*, July, 1898. JACKSON CO. Without locality, *Lapham*. MCHENRY CO. Without locality, *Brendel*. MARION CO. Without locality, *M. S. Bebb* in 1860. WABASH CO. Without locality, *Shearer*, Apr., 1895; Mt. Carmel, *Trelease* and *Schneck*, May, 1888. WINNEBAGO CO. Without locality, *M. S. Bebb*, May, 1859.

Poa chapmaniana Scribn.

Chapman's Spear Grass (Fig. 232)

Culms in tufts, 2 to 12 inches tall, cylindrical, erect; sheaths close, smooth; blades 1 to 4 inches long, smooth; spikelets 3- to 7-flowered, 3 to 5 mm. long; lemmas webbed at the base, 5-nerved, the intermediate nerves obscure, the others sometimes pubescent near base.

This species was not distinguished from *P. annua* by the earlier botanists of the state. Brendel seems first to have noticed the difference, stating it was an annual like *P. annua* with a spikelet like that of *P. pratensis*. Schneck spoke of it as a variety of *P. annua* that preferred dry soil in worn-out fields. It is a very distinct species, easily separated from *P. annua*. It also is a winter annual.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Champaign, *Clinton*, May, 1899; Urbana, *Burrill*, June, 1880. CHRISTIAN CO. Taylorville, *Andrews*, May, 1894 and 1899. EFFINGHAM CO. Edgewood, *Holden*, May, 1898. MARION CO. Without locality, *M. S. Bebb* in 1861; Salem, *M. S. Bebb*; Odin, *Greene* in 1908. MENARD CO. Without locality, *Hall* in 1861. PEORIA CO. Peoria, *Brendel*, June, 1859 and 1860. ST. CLAIR CO. Without locality, *Brendel*; Mascoutah, *Welsch*. WABASH CO. Without locality, *Schneck*, May, 1897; without locality, *Shearer*; Mt. Carmel, *Schneck*, May, 1904; Mt. Carmel, *Trelease* and *Schneck*, May, 1888.

Poa compressa L.

Canada Blue Grass. Wire Grass (Fig. 233)

Lapham '57, 546, 579; Patterson '76, 51; Flagg '78, 281; Brendel '87, 64; Higley and Raddin '91, 144; Huett '97, 130; Cowles '00, 91, 158, 176; Gleason '10, 149; Gates '12, 355; Sherff '13, 595.

Culms strongly flattened, usually bent at the base and arising from long, running rootstocks; sheaths loose, smooth; blades 1 to 4 inches long, rough above; panicles narrow, densely flowered; spikelets variable as to size, 3- to 9-flowered, 4 to 6 mm. long, usually with a bronze tinge; lemmas webbed at base, 2 to 2.5 mm. long, obscurely nerved, the midnerve usually pubescent about to the middle, the others only at the base.

Poa compressa is one of our most common grasses, altho it was introduced from Europe. It has made its way into all the patches of original prairie examined, and seems to be found thruout the state. When growing, it is easily recognized by the flat stem and long rootstocks. It makes a close, dense sod and is often used as a lawn grass, especially where there is competition with the crab grasses, etc., which often drive out the Kentucky blue grass, more commonly used in lawns. It is also a valuable pasture grass.

ILLINOIS SPECIMENS: Without locality, *M. S. Bebb* in 1860; without locality, *Vasey*. CHAMPAIGN CO. Urbana, *Clinton*, June, 1897; Urbana, *Seymour* in 1880; Seymour, *Tsou*, Oct., 1913; Champaign, *Waite*, June, 1886; Seymour, *Chien* in 1914. CHRISTIAN CO. Taylorville, *Andrews*, June, 1899. COOK CO. Tracy, *R. Bebb*, July, 1912; Hyde Park, Chicago, *A. Chase*, Aug., 1903; Evanston, *Shipman*, Sept., 1875. DU PAGE CO. Hinsdale, *Smith*, Sept., 1902. JO DAVIESS CO. Without locality, *Pepoon*. HENDERSON CO. Oquawka, *Patterson*, June, 1872. LAKE CO. Beach, *Gates*, July, 1908; near Waukegan, *Gates* 2860. MCHENRY CO. Algonquin, *Nason*, June, 1878. MARION CO. Without locality, *M. S. Bebb* in 1860; Salem, *M. S. Bebb* in 1860. MENARD CO. Athens, *E. Hall*, July, 1864. PEORIA CO. Peoria, *Brendel* in 1859. PIATT CO. White Heath, *Mosher*, May, 1914. SALINE CO. Harrisburg, *Gibbs*, Oct., 1908. STARK CO. Wady Petra, *V. H. Chase* 1462. VERMILION CO. Muncie, *Mosher*, June, 1914. WABASH CO. Without locality, *Schneck*, June, 1904; without locality, *Shearer;* Connor, *Schneck*, Sept., 1899; Old Palmyra, *Schneck*, June, 1900. WILL CO. Joliet, *Skeels*, June, 1904.

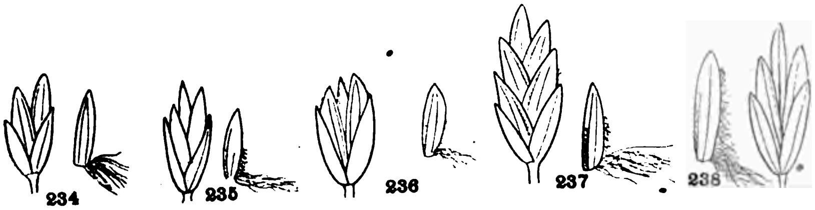
Poa debilis Torr.

Weak Spear Grass (Fig. 234)

Culms weak and slender; sheaths smooth, much shorter than the internodes; blades 1 to 5 inches long, about 2 mm. wide, smooth; panicle few-flowered, the branches slender, drooping; spikelets 2- to 4-flowered, 3 to 4 mm. long; lemmas smooth, webbed at the base.

A rare species in Illinois, found only in damp woods.

ILLINOIS SPECIMENS: Without locality, *Hill*. COOK CO. Glencoe, *Hill*, June, 1913. JO DAVIESS CO. Without locality, *Pepoon* .05.



Figs. 234–238.—Spikelets: 234, *P. debilis;* 235, *P. palustris;* 236, *P. sylvestris;* 237, *P. pratensis;* 238, *P. wolfii*

Poa palustris L.

Fowl Meadow Grass. False Redtop (Fig. 235)

Poa serotina, Lapham '57, 578; Vasey '61, 671; Babcock '73, 97; Patterson '76, 51; Flagg '78, 281; Brendel '87, 64; Higley and Raddin '91, 144. *Poa triflora*, Sherff '12, 419; Sherff '13, 595. *Poa flava*, Britton '07, 139.

Culms 1 to 5 feet tall; sheaths rather loose, smooth; ligule 3 to 5 mm. long; blades 3 to 6 inches long, 2 to 4 mm. wide; panicles oblong, often purplish, rather loosely flowered and delicate; spikelets 2- to 4-flowered, 3 to 4 mm. long; lemmas 2.5 to 3 mm. long, copiously webbed at base; the intermediate nerves obscure, the others long, silky pubescent for about half their length.

This grass is a native to the state, usually found in damp meadows or swamps. It is a very good forage grass, resembling somewhat

P. nemoralis, a European species introduced into many parts of this country.

ILLINOIS SPECIMENS: Without locality, *Vasey;* northern Illinois, *M. S. Bebb.* COOK CO. Skokie Marsh, Glencoe, *Sherff,* June, 1911; Hyde Park, Chicago, *Babcock* in 1873. DU PAGE CO. Hinsdale, *Smith,* May, 1903; Naperville, *Umbach,* June, 1895. JO DAVIESS CO. Without locality, *Pepoon.* KANKAKEE CO. Kankakee, *Hill* 244 in 1873. MCHENRY CO. Without locality, *Brendel;* Ringwood, *Vasey.* PEORIA CO. Peoria, *Brendel* in 1859. STARK CO. Wady Petra, *V. H. Chase* 1459, 1517, 1881.

Poa pratensis L.

Meadow Grass. Spear Grass. June Grass. Kentucky Blue Grass

(Fig. 237)

Lapham '57, 546, 579; Babcock '73, 97; Patterson '76, 51; Flagg '78, 281; Brendel '87, 64; Higley and Raddin '91, 145; Huett '97, 130; Cowles '00, 106, 158; Gleason '07, 182; Gleason '10, 149; Gates '12, 355; Sherff '12, 420; Sherff '13, 595.

Culms cylindrical, from long, running rootstocks; sheaths smooth, the lower overlapping, the upper often shorter than the internodes; ligule about 1.5 mm. long; blades longest at the base, from 1 to 8 inches long, the basal blades longest, 1 to 6 mm. wide; panicle densely flowered; spikelets 3- to 5-flowered, 4 to 6 mm. long; lemmas distinctly 5-nerved, 3 mm. long, copiously webbed at base, the marginal and midnerves pubescent, the others smooth.

This species is native to Illinois and is found all over the state in fields and meadows. It is a popular pasture and lawn grass all over the country.

ILLINOIS SPECIMENS: Without locality, *Lapham.* CHAMPAIGN CO. Urbana, *Clinton,* May, 1897 and 1900; Urbana, *Seymour,* May, 1880; Seymour, *Chien,* May, 1914; Champaign, *Mosher,* Oct., 1913. COOK CO. Ravenswood, *Gates,* June 1906; Hyde Park, Chicago, *Gates,* June, 1906; Chicago, *Lansing,* 216; Evanston, *Shipman.* DU PAGE CO. Naperville, *Umbach,* May, 1898. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon.* HENDERSON CO. Oquawka, *Patterson,* May, 1872. HENRY CO. Galva, *V. H. Chase* 1741. KANE CO. Elgin, *Vasey.* LAKE CO. Beach, *Gates,* June, 1909; north of Waukegan, *Gates,* 3037. MCHENRY CO. Without locality, *Brendel;* Algonquin, *Nason.* PEORIA CO. Peoria, *McDonald,* June, 1901; Peoria, *Brendel.* PIATT CO. White Heath, *Mosher,* May, 1914. ST. CLAIR CO. East St. Louis, *Eggert,* May, 1878; Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase,* May, 1898. VERMILION CO. Muncie, *Mosher,* May, 1914. WABASH CO. Key's Hill, *Schneck,* June, 1905; Mt. Carmel, May, 1880. WOODFORD CO. Without locality, *McDonald,* June, 1889.

Poa sylvestris Gray

(Fig. 236)

Patterson '76, 51; Flagg '78, 281; Brendel '87, 64; Huett '97, 130.

Culms 1 to 3 feet tall; sheaths smooth, shorter than the internodes; ligule 1 mm. long or less; blades 1 to 8 inches long, 2 to 6 mm. wide, the basal ones always longer; panicle open, somewhat oblong, not densely flowered; spikelets 2- to 4-flowered, 2.5 to 4 mm. long, nearly as broad; lemmas about 2.5 mm. long, webbed at base, the nerves all prominent, the midnerve pubescent to the top.

This native species is found in woods and shady places. It is easily distinguished from *P. palustris* by its broader spikelets and short ligule.

ILLINOIS SPECIMENS: Without locality, *Vasey;* southern Illinois, *Lapham.* CHAMPAIGN CO. Urbana, *Clinton,* May, 1900; Urbana, *Gleason,* June, 1900. DU PAGE CO. Hinsdale, *Smith,* June, 1903. FULTON CO. Without locality, *Pepoon;* Canton, *Wolf.* MACON CO. Without locality, *Clokey* 2444. MARSHALL CO. Steuben township, *V. H. Chase* 1796. JO DAVIESS CO. Without locality, *Pepoon.* MENARD CO. Athens, *Hall,* June, 1864. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* June, 1900. PIATT CO. White Heath, *Mosher,* May, 1915. STARK CO. Wady Petra, *V. H. Chase* 1429. VERMILION CO. Muncie, *Mosher,* May, 1914. WABASH CO. Without locality, *Shearer;* Mt. Carmel, *Schneck,* May, 1880; Hanging Rock, *Schneck,* May, 1905; Hurd's Ferry, *Schneck,* July, 1900.

Poa wolfii Scribn.

(Fig. 238)

Culms slender, smooth, 1 to 3 feet tall; sheaths smooth; blades mostly clustered at the base, 1 to 8 inches long, 2 mm. or less in width; panicle open, branches very slender, usually ascending; spikelets 2- to 4-flowered, 5 to 6 mm. long; lemmas 4 mm. long, copiously webbed at base, nerves all prominent, the lateral and midnerves pubescent for more than half their length, the intermediate nerves smooth.

Illinois is the type locality for this species, which was named after one of its earlier collectors, J. Wolf. The plant is comparatively rare.

ILLINOIS SPECIMENS: Without locality, *Wolf* in 1883. FULTON CO. Without locality, *Brendel* in 1860; Copperas Creek, *Wolf,* June, 1883. HENDERSON CO. Oquawka, *Patterson.* PEORIA CO. Peoria, *Brendel.*

The following species of Poa have been reported from Illinois, but no authentic specimens have been found as yet.

Poa brachyphylla Schult.—This was reported as *P. brevifolia* by Lapham ('57, 546, 578), Flagg ('78, 281), and Higley and Raddin ('91, 145).

Poa nemoralis L.—This species was reported by Lapham ('57, 546, 579; Plate 2, Fig. 12), who says it is a native both of this country and Europe. It seems probable that he did not have the species as it is understood at present.

Poa trivialis L.—Flagg ('78, 281) cites this as occurring in Illinois, having been introduced from Europe. It is probable that it was cultivated here for only a short time.

55. **PANICULARIA** Fabr.

Manna Grass

These grasses are all found in moist situations. They are perennials with flat leaves and terminal panicles. The ligules are membranous. The spikelets are 3- to 15-flowered; the lemmas usually very prominently nerved, with a narrow, transparent margin. The glumes are unequal and much shorter than the spikelets.

a. Spikelets 2 to 8 mm. long, the length never three times the width; panicles open and spreading.

  b. Spikelets 3 to 4 mm. wide; nerves on the lemmas not prominent. *P. canadensis*

  bb. Spikelets 1 to 2.5 mm. wide; nerves on the lemmas very prominent and with deep furrows between.

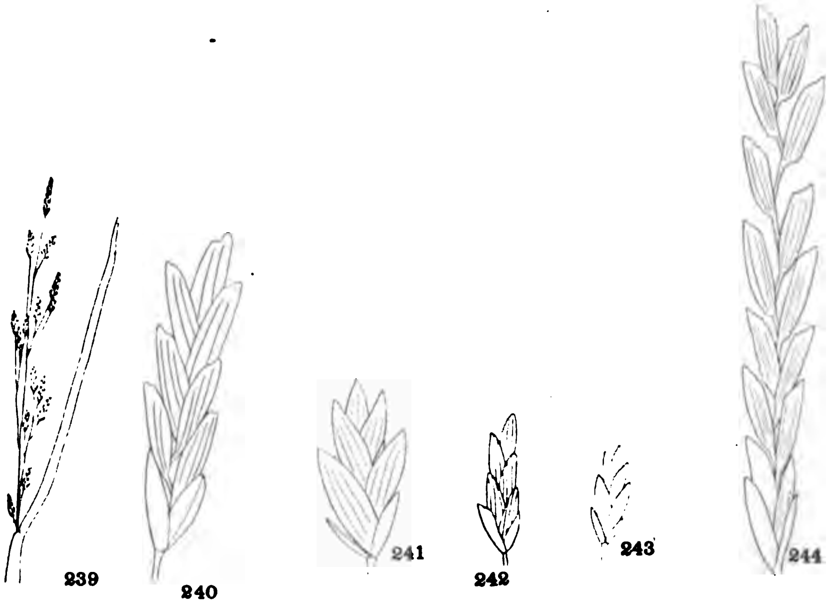
    c. Spikelets 3 to 4 mm. long, the lemmas 1.5 mm. long, glumes short and rounded. *P. nervata*

    cc. Spikelets 4 to 6 mm. long, the lemmas 2 mm. long, glumes oblong. *P. grandis*

aa. Spikelets 10 to 25 mm. long, the length always more than three times the width; panicle narrow, the branches erect.

  b. Spikelets nearly sessile; 15 to 20 mm. long; lemmas firm, hispidulous; 4 to 4.5 mm. long. *P. septentrionalis*

  bb. Spikelets slender pediceled; 10 to 15 mm. long; lemmas thin, rough only on the nerves, 3.5 to 4 mm. long. *P. borealis*



Figs. 239-244.—239, *P. borealis*, inflorescence; 240, *P. borealis*, spikelet; 241, *P. canadensis*, spikelet; 242, *P. grandis*, spikelet; 243, *P. nervata*, spikelet; 244, *P. septentrionalis*, spikelet

Panicularia borealis Nash

Slender Manna Grass (Figs. 239 and 240)

Culms bent at base and rooting at the nodes, 2 to 5 feet tall; sheaths overlapping, usually smooth, the upper one inclosing the base of the panicle; blades narrow, 4 to 20 inches long, 2 to 10 mm. broad, usually folded, ending in a sharp point; panicle very narrow, with the branches erect or appressed; spikelets 10 to 15 mm. long, the pedicels one-third to two-thirds the length of the spikelets, 7- to 13-flowered; lemmas thin, 3.5 to 5 mm. long, the nerves rough.

This is a northern species, rare in Illinois. It closely resembles *P. septentrionalis,* from which it is most easily separated by its pediceled spikelets. It is found in shallow water, or in moist soil along the edges of streams and ponds.

JO DAVIESS CO. Margin of ponds near E. Dubuque, *Pepoon* 426. STARK CO. Pond northeast of Wady Petra, *V. H. Chase* 100.

Panicularia canadensis (Michx.) Kuntze

Rattlesnake Grass. (Fig. 241)

Glyceria canadensis, Lapham '57, 546, 576; Babcock '73, 97; Patterson '76, 50; Flagg '78, 281; Brendel '87, 88; Higley and Raddin '91, 145; Huett '97, 130.

Culms erect, 2 to 3 feet tall; sheaths considerably shorter than the internodes, except at the base of the culm, where they overlap; blades rough, 6 to 18 inches long, 4 to 8 mm. wide; panicle 6 to 10 inches long, nearly as broad, the branches very slender, usually drooping; spikelets 5- to 12-flowered, 5 to 8 mm. long, flattened; lemmas broad 3 to 4 mm. long, faintly nerved.

This grass is one of the most beautiful of the grasses found in the state. It is also a northern species. It is found in wet places.

ILLINOIS SPECIMENS: Northern Illinois, *Brendel.* FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon.* PEORIA CO. Peoria, *Brendel.*

Panicularia grandis (Wats.) Nash

Reed Meadow Grass (Fig. 242)

Culms erect, stout, soft and spongy, 3 to 5 feet tall; sheaths loose, usually smooth; blades usually smooth beneath, rough above, 8 to 12 inches long, 6 to 16 mm. wide; panicle 8 to 16 inches long, nearly as broad, the branches drooping; spikelets numerous, 4- to 7-flowered, 4 to 6 mm. long; florets purple, the lemmas about 2 mm. long, distinctly 7-nerved; glumes whitish, 1-nerved.

This species resembles *P. nervata* in habit but is a larger, more robust species. The panicle of *P. nervata* is much smaller and usually green, while that of *P. grandis* is very large and nearly always purple; the leaves of *P. grandis* are usually much broader. This species is found only in the extreme northern part of the state, while *P. nervata* is found over the entire state.

JO DAVIESS CO. Warren, *Umbach,* July, 1896.

Panicularia nervata (Willd.) Kuntze

Nerved Manna Grass. Fowl Meadow Grass (Fig. 243)

Glyceria nervata, Lapham '57, 546, 577 (Plate 2, Fig. 2); Patterson '76, 50; Flagg '78, 281; Brendel '87, 63; Higley and Raddin '91, 145; Huett '97, 130; Gates '12, 355; Gleason '12, 44; Sherff '12, 419; Sherff '13, 595.

Culms slender, erect, often in large bunches, 1 to 3 feet tall; sheaths usually smooth, overlapping at the base of the culm, the upper sheaths usually partially closed; blades 6 to 12 inches long, 4 to 10 mm. wide, rough above, smooth beneath; panicle 4 to 8 inches long, often purple, the branches usually drooping, spikelets 3- to 7-flowered, 3 to 4 mm. long; lemmas distinctly 7-nerved, about 1.5 mm. long.

This is one of the native grasses much liked by stock and could be introduced into damp pasture lands. The office of Poisonous Plant Investigations, U. S. Dept. of Agriculture, has found it to contain a small quantity of hydrocyanic acid, enough to be poisonous if a quantity of the grass is eaten. It is common in Illinois in most situations.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Champaign, *Waite*, June, 1888; Mahomet, *Clinton*, Oct., 1898; Champaign, *Waite*, June, 1886; Urbana, *Clinton*, Sept., 1899; Urbana, *Seymour* and *Butts*, June, 1880. CHRISTIAN CO. Taylorville, *Andrews*. COOK CO. Chicago, *Babcock*, July, 1869; Evanston, *Shipman*, Sept., 1875; Lake Forest, *Jensen*, June, 1895; near Chicago, *McDonald*, June, 1891. JO DAVIESS CO. Without locality, *Pepoon* 683. KANKAKEE CO. Kankakee, *Hill*, May, 1870. HENDERSON CO. Oquawka, *Patterson*, June, 1872. LAKE CO. Beach Area, *Gates* 2810. MCHENRY CO. Algonquin, *Nason*, MACOUPIN CO. Carlinville, *Robertson*, June, 1882. MADISON CO. Venice, *Eggert*, July, 1877. MARION CO. Without locality, *Lapham*. MENARD CO. Without locality, *Hall* in 1861. PEORIA CO. Peoria, *Brendel*; Peoria, *McDonald*, Aug., 1896. ST. CLAIR CO. Mascoutah, *Welsch*. VERMILION CO. Muncie, *Mosher*, May, 1914. WABASH CO. Without locality, *Schneck*, July, 1888; without locality, *Shearer*; Paton, *Schneck*, July, 1879.

Panicularia septentrionalis Hitchc.

Floating Manna Grass (Fig. 244)

Glyceria fluitans, Lapham '57, 546, 577; Babcock '73, 97; Patterson '76, 51; Flagg '78, 281; Brendel '87, 63; Higley and Raddin '91, 145; Huett '97, 130. *Glyceria septentrionalis*, Sherff '12, 417; Sherff '13, 595.

Culms erect, 3 to 6 feet tall, usually large, soft, and spongy; lower sheaths overlapping, the upper closed nearly to the summit; ligule 5 or 6 mm. long; blades 4 to 9 inches long, 6 to 8 mm. wide; slightly rough; panicles very narrow, the branches erect or appressed, sometimes spreading in flower; spikelets 7- to 12-flowered, 20 to 25 mm. long, nearly sessile; lemmas rough all over, 4 to 4.5 mm. long.

This species is found in shallow water with the leaves floating, or where there is very wet soil. It is an excellent grass for swampy meadows. Cattle are very fond of it.

ILLINOIS SPECIMENS: Without locality, *Vasey*; northern Illinois, *Vasey*; southern Illinois, *Lapham*. CHAMPAIGN CO. Rantoul, *Clinton*, Sept., 1897. CHRISTIAN CO. Taylorville, *Andrews*. COOK CO. Chicago, *Moffatt*, July, 1891; Evanston, *Shipman*, Sept., 1875; Chicago, *Scammon*, July, 1859. DU PAGE CO. Without locality, along ditches, *Moffatt*, July, 1891. HENDERSON CO. Oquawka, *Patterson*, July, 1872. KANKAKEE CO. Bourbonnais, *Hill*, July, 1873. LAKE CO. Gilmer, *Gates* 1712; Lake Zurich, *Hill*, June, 1899. MCHENRY CO. Ringwood, *Vasey*. MACOUPIN CO. Macoupin, *Robertson*, July, 1883. MENARD CO. Without locality, *Hall* in 1861. PEORIA CO. Peoria, *Brendel*. PIATT CO. Monticello, *Seymour* and *Waite*, July, 1880. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase*, July, 1898. WABASH CO. Without locality, *Schneck*, July, 1900; without locality, *Shearer*; Mt. Carmel, *Schneck*, July, 1879. WILL CO. Joliet, *Skeels*, June, 1904.

Panicularia pallida (Torr.) Kuntze (*Glyceria pallida Trin.*).—This was reported by Vasey ('61, 671) and Flagg ('78, 281) from Illinois. The specimens in the University herbarium labeled *Glyceria pallida* are a species of Poa which it strongly resembles. No other specimens have been seen and its occurrence in Illinois is doubtful.

56. FESTUCA L.

Fescue Grass

The species of Festuca have 2- to many-flowered spikelets arranged in open or contracted panicles. The glumes are narrow, keeled, and pointed. The lemmas are firm, not keeled but rounded on the back, often awned or awn-pointed. The leaves are narrow, in some species involute, and the ligule is very short and membranous. There are both annual and perennial species.

- a. Lemmas awnless or very rarely awn pointed; leaves flat.
  - b. Panicle narrow, erect, branches short; lemmas 5 to 7 mm. long. *F. elatior*
  - bb. Panicle open, rarely erect, branches long; lemmas 4 to 4.5 mm. long.
    - c. Spikelets broad, short pediceled, aggregated at the ends of the rather short panicle branches. *F. shortii*
    - cc. Spikelets narrow, long pediceled, scattered in an open panicle with long, slender branches.
- aa. Lemmas awned, leaves involute. *F. obtusa*
  - b. Stamens 1 or 2; lemmas rough; annual. *F. octoflora*
  - bb. Stamens 3; lemmas smooth; perennial. *F. ovina*

Festuca elatior L.

Tall or Meadow Fescue (Fig. 245)

Babcock '73, 97; Patterson '76, 51; Flagg '78, 282; Higley and Raddin '91, 145; Huett '97, 130.

Culms erect, in loose bunches, 1.5 to 5 feet tall, smooth; sheaths smooth, or slightly rough at the top; blades 4 to 16 inches long, 4 to 8 mm. wide, flat, rough on the upper surface, auricle well-developed; panicle 4 to 8 inches long, narrow, rather loose-flowered; spikelets 5- to 9-flowered, 9 to 11 mm. long; lemma 5 to 7 mm. long, faintly nerved.

This perennial species was introduced from Europe, but is now naturalized thruout the state. It is an excellent forage grass and much cultivated for hay.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Champaign, *Waite*, June, 1881 and 1886; Urbana, *Seymour*, June, 1880. FULTON CO. Canton, *Wolf*. KANKAKEE CO. Kankakee, *Hill*, July, 1874. PEORIA CO. Peoria, *Brendel*, July, 1883; Peoria, *McDonald*, July, 1903. PIATT CO. White Heath, *Mosher*, May, 1913. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase* 58. VERMILION CO. Muncie, *Mosher*, May, 1914. WABASH CO. Without locality, *Shearer;* Mt. Carmel, *Schneck*, July, 1878. WILL CO. Troy township, *Hill* 32 in 1907; Mokena, *Hill* 14 in 1910.

Festuca obtusa Spreng.

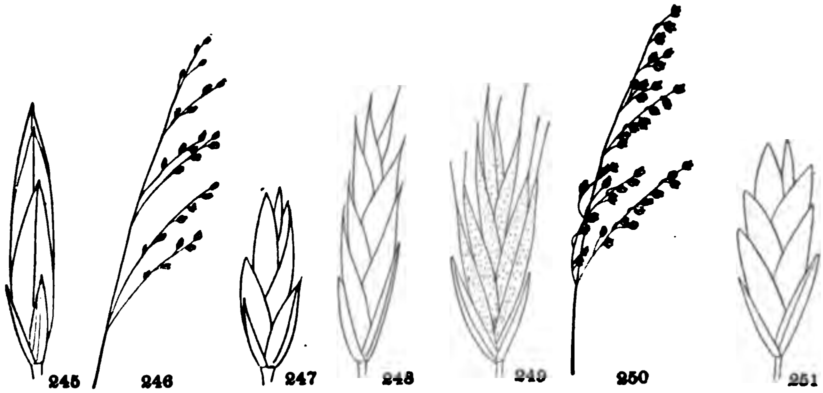
Nodding Fescue (Figs. 246 and 247)

Festuca nutans, Engelmann '44, 103; Lapham '57, 547, 582 (Plate 3, Fig. 1); Babcock '73, 97; Patterson '76, 51; Flagg '78, 282; Brendel '87, 64; Higley and Raddin '91, 145.

Culms single or a few together, 1 to 3 feet tall; sheaths often slightly pubescent; blades rough above, 4 to 12 inches long, 4 to 7 mm. wide; panicle usually nodding, the branches bearing spikelets near the ends; spikelets 3- to 5-flowered, typically 3-flowered, 5 to 7 mm. long, always much longer than broad; lemmas about 4 mm. long with a thin white or transparent margin; second glume 3 mm. long.

This is a native species which is found in damp or shady woods and thickets.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Urbana, *Waite*, June, 1886; Urbana, *Clinton*, May, 1898; Mahomet, *Wright*, June, 1898; Mahomet, *Clinton*, May, 1900. CHRISTIAN CO. Taylorville, *Andrews*. DU PAGE CO. Hinsdale, *Smith*, June, 1903; Wheatland, *Umbach*, July, 1898; Naperville, *Umbach*, July, 1898. JACKSON CO. Without locality, *Lapham* in 1857. JO DAVIESS CO. Without locality, *Pepoon*. HENDERSON CO. Oquawka, *Patterson*, June, 1874. LA SALLE CO. Near Starved Rock, *A. Chase*, July, 1901. MCHENRY CO. Algonquin, *Nason*. MACOUPIN CO. Carlinville, *Robertson* in 1898. MARION CO. Without locality, *M. S. Bebb* in 1860. MARSHALL CO. Near Lawn Ridge, *V. H. Chase* 1493. MASON CO. Without locality, *Clokey*. PEORIA CO. Princeville, *V. H. Chase*, June, 1897; Peoria, *McDonald*, June, 1890; Peoria, *Brendel*. PIATT CO. White Heath, *Mosher*, May, 1914. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Woods along Spoon river, *V. H. Chase* 1448. VERMILION CO. Muncie, *Mosher*, May, 1914. WABASH CO. Without locality, *Shearer*. WILL CO. Joliet, *Skeels*, June, 1904.



Figs. 245–251.—245, *F. elatior*, spikelet; 246, *F. nutans*, inflorescence; 247, *F. nutans*, spikelet; 248, *F. ovina*, spikelet; 249, *F. octoflora*, spikelet; 250, *F. shortii*, inflorescence; 251, *F. shortii*, spikelet

Festuca octoflora Walt.

Slender Fescue (Fig. 249)

Festuca tenella, Lapham '57, 547, 581; Patterson '76, 51; Flagg '78, 282; Brendel '87, 64; Higley and Raddin '91, 145; Huett '97, 130. *Festuca octoflora*, Gleason '10, 149; Gates, '12, 355.

Culms slender, often tufted, 2 to 16 inches tall; sheaths smooth, shorter than the internodes; blades very short, 1.5 to 4 inches long, involute; panicle narrow, contracted, spike-like, 1 to 5 inches long; spikelets 6- to 13-flowered, 5 to 12 mm. long; lemmas rough 3 to 5 mm. long, the awn about the same length.

This annual species is found in dry, open country, usually where the soil is very poor.

ILLINOIS SPECIMENS: Without locality, *Vasey;* southern Illinois, *Lapham* in 1857. CHAMPAIGN CO. Champaign, *Seymour* and *Waite,* June, 1884; Champaign, *Seymour,* June, 1884. COOK CO. Evanston, *Johnston* in 1891. HANCOCK CO. Warsaw, *Mead,* July, 1842. JACKSON CO. Makanda, *Gleason,* June, 1903. JO DAVIESS CO. Without locality, *Pepoon* 145; Hanover, *Gleason* and *Gates* 2571 KANKAKEE CO. Kankakee, *Hill* 33 in 1872. LAKE CO. Waukegan, *Gates* 2468. LA SALLE CO. Starved Rock, *Gates* 3191. MACON CO. Decatur, *Clokey,* June, 1899. MACOUPIN CO. Carlinville, *Robertson,* May, 1883. MARION CO. Without locality, *M. S. Bebb* in 1860. MARSHALL CO. Near Lawn Ridge, *V. H. Chase* 1494. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* June, 1889. PIATT CO. White Heath, *Mosher,* May, 1914. POPE CO. Herod, *Clinton,* July, 1898. ST. CLAIR CO. Without locality, *Eggert,* Aug., 1874; Mascoutah, *Welsch.* VERMILION CO. Muncie, *Mosher,* May, 1914. WABASH CO. Without locality, *Schneck,* June, 1900; Old Palmyra, *Schneck,* May, 1883; Keensburgh, *Schneck,* June, 1898.

Festuca ovina L.

Sheep's Fescue (Fig. 248)

Culms erect in close bunches, 6 inches to 2 feet tall; sheaths usually smooth; blades pale green, involute, 2 to 5 inches long, the lower ones longest; panicle slender and spike-like, 2 to 4 inches long; spikelets 5 to 7.5 mm. long; lemmas smooth, 3 to 3.5 mm. long.

There is a native form of this species and also one introduced from Europe in seed mixtures for pastures and parks. A variety, *F. ovina duriuscula,* also introduced from Europe, is taller and has lemmas about 6 mm. long.

ILLINOIS SPECIMENS: Without locality, *Vasey.* CHAMPAIGN CO. Crystal Lake Park, Urbana, *Trelease,* May, 1914; Urbana, *Lantz,* 1914; Urbana, *Waggoner,* May, 1914.

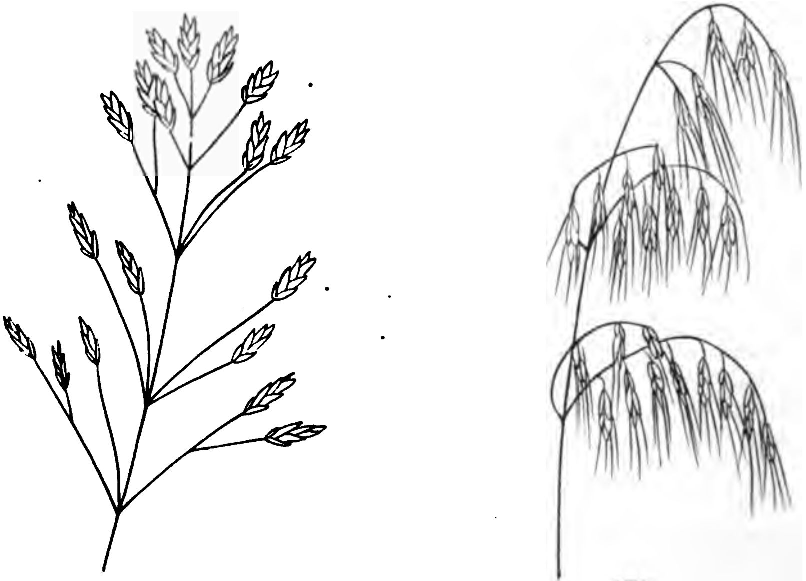
Festuca shortii Kunth

(Figs. 250 and 251)

Culms in small bunches or single, 1 to 4 feet tall; sheaths usually smooth, shorter than the internodes; blades 4 to 12 inches long, 2 to 4 mm. wide, often involute in drying; panicle open, the naked branches bearing few- to several-clustered, short-pediceled spikelets near the ends; spikelets usually 5- to 9-flowered, typically more than 3-flowered, 5 to 7 mm. long; when mature the length and breadth nearly equal; lemmas 4.5 mm. long; second glume 4 to 5 mm. long.

This species is much more distinct than perhaps the description would lead one to believe. It was formerly included with *Festuca obtusa,* but is easily distinguished by the panicle. That of *Festuca* *obtusa* is slender, graceful, and few-flowered, while in *Festuca shortii* it is broader, and thick and heavy in appearance. It is found in woods, but also in open damp places.

ILLINOIS SPECIMENS: Without locality, ***Mead;*** without locality, ***Vasey.*** CHAMPAIGN CO. Urbana, ***Burrill, Seymour*** and ***Waite*** in 1884; Urbana, ***Seymour,*** June, 1880. FRANKLIN CO. Benton, ***Patterson,*** June, 1872. FULTON CO. Without locality, ***Wolf.*** HENDERSON CO. Oquawka, ***Patterson.*** MARION CO. Without locality, ***M. S. Bebb*** in 1860; Salem, ***M. S. Bebb.*** MENARD CO. Without locality, ***Hall.*** PEORIA CO. Peoria, ***Brendel.*** ST. CLAIR CO. Mascoutah, ***Welsch.*** STARK CO. East of Wady Petra, ***V. H. Chase,*** 1228. WABASH CO. Without locality, ***Shearer.***



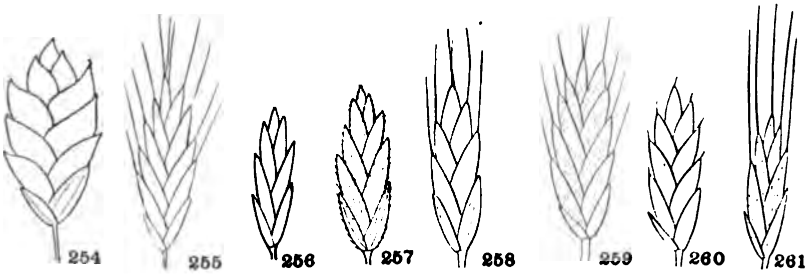
252 **253**

Figs. 252–253.—Inflorescences: 252, *B. inermis;* 253, *B. tectorum*

57. BROMUS L.

The annual species of this genus have been introduced from Europe and are more or less serious pests. The native species are perennials mostly confined to woods and shady places and are of no economic importance. The spikelets are large, usually many-flowered; the lemmas are two-toothed at the apex and often bear an awn from between the teeth; the glumes are unequal, the second larger. The inflorescence is of panicles, the spikelets either erect or drooping. The leaves are flat, the ligules membranous, seldom over 1 or 2 mm. in length. The species are exceedingly variable, and therefore difficult to classify correctly.

a. Lemmas smooth or scabrous, not pubescent.
  b. Second glume 3-nerved.
    c. Lemmas awnless or awn-pointed; plants generally smooth thruout; perennial by long, running rootstocks. *B. inermis*
    cc. Lemmas with long, scabrous awns; sheaths pilose-pubescent; annuals. *B. villosus*
  bb. Second glume 5- to 9-nerved; plants without running rootstocks.
    c. Spikelets with the width more than half the length; lemmas very broad, awnless or awn-pointed. *B. brizaeformis*
    cc. Spikelets with the width always less than half the length; lemmas narrow or ovate, with an awn at least 3 mm. long.
      d. Lemmas thick, the margin inrolled at maturity, the awn slender and weak, 3 to 5 mm. long; sheaths glabrous. *B. secalinus*
      dd. Lemmas thin, with a transparent edge, not inrolled at maturity, the awn strong, 5 to 8 mm. long; sheaths pubescent. *B. pratensis*
aa. Lemmas pubescent, either along the margin or over the entire surface.
  b. Awn as long or longer than the lemma; annual species with the panicle branches drooping. *B. tectorum*
  bb. Awn considerably shorter than the lemma.
    c. Lemmas pubescent along the margin and sometimes at the base. *B. ciliatus*
    cc. Lemmas evenly pubescent over the entire surface.
      d. Lemmas densely long, silky pubescent; lemma 8 to 10 mm. long, the awn 2 to 3 mm. *B. kalmii*
      dd. Lemmas sparsely short, appressed pubescent, 10 to 12 mm. long, the awn 4 to 8 mm. *B. purgans*



Figs. 254–261.—Spikelets: 254, *B. brizaeformis;* 255, *B. ciliatus;* 256, *B. inermis;* 257, *B. kalmii;* 258, *B. pratensis;* 259, *B. purgans;* 260, *B. secalinus;* 261, *B. tectorum*

Bromus brizaeformis Fisch. and Mey.

(Fig. 254)

Culms 6 inches to 2 feet tall, smooth, slightly pubescent at the nodes; sheaths pubescent, shorter than the internodes; blades 4 to 8 inches long, 1 to 4 mm. wide; panicle open, drooping; spikelets 10 to 20 mm. long and 9 to 13 mm. wide, lemmas awnless, smooth, 8 to 10 mm. long.

This annual species was introduced from Europe and is rare in America.

RICHLAND CO. Parkersburg, *Ridgeway,* June, 1902.

Bromus ciliatus L.

Fringed Brome Grass (Fig. 255)

Lapham '57, 547, 583 (Plate 3, Fig. 2); Babcock '73, 97; Patterson '76, 51; Flagg '78, 282; Brendel '87, 64; Higley and Raddin '91, 146; Huett '97, 131.

Culms slender, 2 to 4 feet tall; sheaths retrorsely pubescent; blades 8 to 15 inches long, 4 to 12 mm. wide, rough and slightly pubescent; panicle spreading, often nearly as broad as long, usually drooping; spikelets 5- to 9-flowered, 15 to 25 mm. long; glumes smooth; lemmas 10 to 12 mm. long, pubescent along the edge and sometimes near the base, but smooth on the remainder of the surface; awn 3 to 5 mm. long.

Bromus ciliatus is one of the native perennial species. It grows in damp places, usually in the woods.

ILLINOIS SPECIMENS: Without locality, *Vasey;* without locality, *Bebb* in 1860. CHAMPAIGN CO. Mahomet, *Wright*, June, 1898; Mahomet, *Burrill* and *Seymour*, Aug., 1888. COOK CO. Chicago, *Babcock*, July, 1873; Evanston, *Shipman*. FULTON CO. Without locality, *Pepoon*. JACKSON CO. Without locality, *Lapham*. JO DAVIESS CO. Without locality, *Moffatt;* without locality, *Pepoon*, Aug., 1912. KANKAKEE CO. Kankakee, *Hill*, July, 1873. MACOUPIN CO. Carlinville, *Robertson*, June, 1882. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald*, June, 1896; Mossville, *A. Chase* 883. POPE CO. Herod, *Clinton*, Aug., 1898. ST. CLAIR CO. Mascoutah, *Welsch*. WABASH CO. Near Paton, *Schneck*, June, 1879.

Bromus inermis Leyss.

Hungarian Brome Grass (Figs. 252 and 256)

Culms in tufts from creeping rootstocks, smooth, 1 to 4 feet tall; sheaths smooth; blades 6 to 10 inches long, 4 to 6 mm. wide, smooth; panicle narrow, the branches ascending; spikelets 6- to 10-flowered, smooth; lemmas 10 to 12 mm. long; awnless or awn-pointed, second glume 3-nerved.

This species, also known as smooth brome grass, makes rank growth, and is gradually spreading over the whole United States. It was introduced as a forage grass, but lately has been considered of little value.

JO DAVIESS CO. Without locality, *Pepoon* .06. LAKE CO. Leithton, *Gates* 1729.1; Ravinia, *Gates* 1678.2. LIVINGSTON CO. Emington, *Wilcox*. STARK CO. Wady Petra, *V. H. Chase*, 1454, also July, 1907. VERMILION CO. Muncie, *Mosher*, May, 1914.

Bromus kalmii A. Gray

Wild Chess (Fig. 257)

Lapham '57, 547, 582; Babcock '73, 97; Patterson '76, 51; Brendel '87, 64; Higley and Raddin '91, 146; Huett '97, 130; Gates '12, 355.

Culms 1.5 to 3 feet tall; sheaths softly pubescent; blades 1 to 8 inches long, 2 to 8 mm. wide, usually softly pubescent on both surfaces; the hairs often long and conspicuous; panicle small, open, branches usually wavy; spikelets 6- to 10-flowered, densely covered with soft, silky pubescence; lemmas 8 to 10 mm. long, the awn 2 to 3 mm. long; second glume 5- to 7-nerved.

This is a native perennial species usually found in dry, waste places, sometimes in woods and shady places. It is distinguished from all other Illinois species by the copious silky pubescence of foliage and spikelets.

ILLINOIS SPECIMENS: Without locality, *Vasey*. DU PAGE CO. Wheatland, *Umbach*, July, 1898. JACKSON CO. Without locality, *Lapham* in 1857. JO DAVIESS CO. Without locality, northern part, *Pepoon* 51. LAKE CO. Beach, *Gates* 2762; marsh near Rockefeller, *Gates* 1741; between Winthrop Harbor and Beach, *Gates*, June, 1908. MCHENRY CO. Algonquin, *Nason*, July, 1878. MENARD CO. Athens, *Hall*. PEORIA CO. Peoria, *Brendel* in 1857.

Bromus pratensis Lam.

(Fig. 258)

Culms 6 inches to 2 feet tall, smooth or slightly pubescent; lower sheaths overlapping and the upper shorter than the internodes, pubescent; blades 4 to 10 inches long, 4 to 7 mm. wide, pubescent on both surfaces; panicle erect, rather narrow; spikelets 6- to 10-flowered; lemma 9 to 10 mm. long, short pubescent, scabrous; awn 5 to 8 mm. long; second glume 5- to 7-nerved.

An annual species introduced from Europe, but only occasionally found in the Middle West.

VERMILION CO. Muncie, *Mosher*, May, 1914. WABASH CO. Near Mt. Carmel, *Shearer*.

Bromus purgans L.

(Fig. 259)

Bromus ciliatus var. *purgans*, Higley and Raddin '91, 146. *Bromus incanus*, Gates '12, 355.

Culms fairly stout, 2 to 5 feet tall; sheaths retrorsely pubescent; blades 6 to 12 inches long, 5 to 15 mm. wide, usually short pubescent on the upper surface; panicle spreading, usually large and nodding; spikelets 7- to 11-flowered; glumes sparsely pubescent, the second 3-nerved; lemmas 10 to 12 mm. long, pubescent over entire surface, the awn 4 to 6 mm. long.

This species is a native of the state. It is usually found in damp shaded places.

CHAMPAIGN CO. Urbana, *Mosher*, May, 1915. CHRISTIAN CO. Taylorville, *Andrews*. COOK CO. Beverly Hills, *R. Bebb*, Sept., 1903; Bowmanvil Woods, Chicago, *Gates*, June, 1908; River Grove, *Hill* 68 in 1897. FULTON CO. Canton, *Wolf*. JO DAVIESS CO. Without locality, *Pepoon* .07. KNOX CO. Williamsfield, *V. H. Chase* 1839. LA SALLE CO. Starved Rock, *A. Chase*, July, 1901. MACOUPIN CO. Without locality, *Robertson*, Aug., 1883. MARSHALL CO. Near Lawn Ridge, *V. H. Chase* 1487. PEORIA CO. Peoria, *Brendel*; Peoria, *McDonald*, July, 1904. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Near Wady Petra, *V. H. Chase* 640, 1538. VERMILION CO. Muncie, *Mosher*, May, 1914. WABASH CO. Without locality, *Shearer*, May, 1899. Hanging Rock, *Schneck*, July, 1905; Grand Rapids, *Schneck*, Aug., 1900.

Bromus purgans incanus Shear.—This variety differs from the species in having densely pubescent or velvety sheaths.

ILLINOIS SPECIMENS: Without locality, *Wolf,* Sept., 1882. FULTON CO. Canton, *Wolf.* PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* July, 1904. WABASH CO. Without locality, *Shearer,* July, 1896; near Mt. Carmel, *Shearer,* July, 1896.

Bromus purgans latiglumis (*B. altissimus* Pursh).—This variety has overlapping sheaths and an unusually large number of leaves. The sheaths are usually smooth except for a ring of hairs where they join the blades.

JO DAVIESS CO. Warren, *Pepoon* 489. KANE CO. Elgin, *Sherff* 1789. STARK CO. Wady Petra, *V. H. Chase* 1265. WABASH CO. Mt. Carmel, *Schneck* in 1879; Hanging Rock, *Schneck.*

Bromus secalinus L.

Cheat, or Chess (Fig. 260)

Lapham '57, 547, 582; Babcock '73, 97; Patterson '76, 51; Flagg '78, 282; Higley and Raddin '91, 146; Huett '97, 130.

Culms 1 to 3 feet tall; sheaths typically smooth, strongly nerved; blades 2 to 8 inches long, 2 to 6 mm. wide, usually smooth, sometimes slightly pubescent; panicle open, branches usually drooping; spikelets 5- to 15-flowered, smooth; lemma 8 to 11 mm. long, thick, the margins inrolled at maturity, awns short and slender, generally 3 to 5 mm. long.

This species was introduced from Europe and has now spread all thru the temperate part of North America. It becomes a serious pest in grain fields. As it is an annual, it should be prevented from ripening seed. All plants should be destroyed when first discovered in order to prevent its spread into new localities.

ILLINOIS SPECIMENS: Without locality, *Vasey.* CHAMPAIGN CO. Urbana, *Clinton,* June, 1888; Urbana, *Seymour,* July, 1878; Champaign, *Seymour,* July, 1878. CHRISTIAN CO. Taylorville, *Andrews;* Taylorville, *De Motte.* COOK CO. Woodlawn, Chicago, *Millspaugh,* June, 1898. DU PAGE CO. Wheaton, *Moffatt,* June, 1892. JO DAVIESS CO. Without locality, *Pepoon.* MACON CO. Decatur, *Clokey* 2586. MACOUPIN CO. Carlinville, *Robertson,* June, 1882. MARION CO. Without locality, *Lapham* in 1857; without locality, *M. S. Bebb* in 1860. PEORIA CO. Peoria, *Brendel* in 1860; Peoria, *McDonald,* July, 1889. ST. CLAIR CO. Mascoutah, *Welsch;* East St. Louis, *Lehenbauer,* May, 1914. STARK CO. Wady Petra, *V. H. Chase* 1453. UNION CO. Cobden, *Earle,* July, 1886. VERMILION CO. Muncie, *Mosher,* May, 1914. WABASH CO. Without locality, *Schneck,* June, 1904. Mt. Carmel, *Schneck,* June, 1897; Timberville, *Schneck,* June, 1879; Old Palmyra, *Schneck,* May, 1881.

Bromus tectorum L.

Downy Brome Grass (Figs. 252 and 261)

Gates '12, 355.

Culms in tufts, slender; sheaths and blades pubescent, the latter 1 to 4 inches long, 2 to 4 mm. wide; panicle densely flowered, drooping; spikelets on slender pedicels, 5- to 8-flowered, pubescent; lemmas 8 to 12 mm. long, awn 12 to 16 mm. long; glumes pubescent, the second glume 3-nerved.

This European species was first observed in Illinois in 1903, and has spread very rapidly since that time. Four years ago, only a few plants were observed within a thirty-mile radius of Urbana; now this species can be found along all railway tracks, around elevators, and in waste places generally. As it is likely to become a serious pest in the state, some pains should be taken to eradicate it when first observed. It is an annual species, and should be easily controlled.

CHAMPAIGN CO. St. Joseph, *Mosher,* June, 1914 and 1915; Champaign, *Mosher,* May, 1913; Urbana, *Mosher,* May, 1915; Urbana, *Trelease,* May, 1914. Seymour, *Mosher,* June, 1914. COOK CO. Hyde Park, Chicago, *A. Chase,* June, 1903. EDGAR CO. Scottland, *Dawson,* May, 1914. JO DAVIESS CO. Without locality, *Pepoon.* PIATT CO. White Heath, *Mosher,* May, 1914. STARK CO. North of Wady Petra, *V. H. Chase* 1203. TAZEWELL CO. Hilton, *McDonald,* June, 1889. VERMILION CO. Muncie, *Mosher,* May, 1914. WABASH CO. Mt. Carmel, *Schneck,* May, 1906; between Mt. Carmel and Paris, *Schneck,* June, 1906.

Bromus villosus Forsk.

Culms 1 to 3 feet tall, smooth; sheaths softly pilose-pubescent; ligule 3 to 4 mm. long; blades pilose, 8 to 10 inches long, 3 to 5 mm. broad; panicle erect or somewhat drooping, rather narrow at first but open in flower; spikelets 3.5 to 5 cm. long; drooping; glumes smooth; lemma scabrous, 25 to 30 mm. long exclusive of the awn; awn stout, scabrous, 3.5 to 5 mm. long. The plants are annuals, easily distinguished by the long, scabrous awns.

This is a Mediterranean species which is now abundant in California, and has recently appeared in Maryland. It is one of the worst weeds which has been introduced into the United States. Not only does it spread rapidly, but the long, stiff, scabrous awns of the fallen florets injure the lining of the mouth and nostrils of grazing cattle. Every precaution should be taken to prevent this species from becoming established in Illinois.

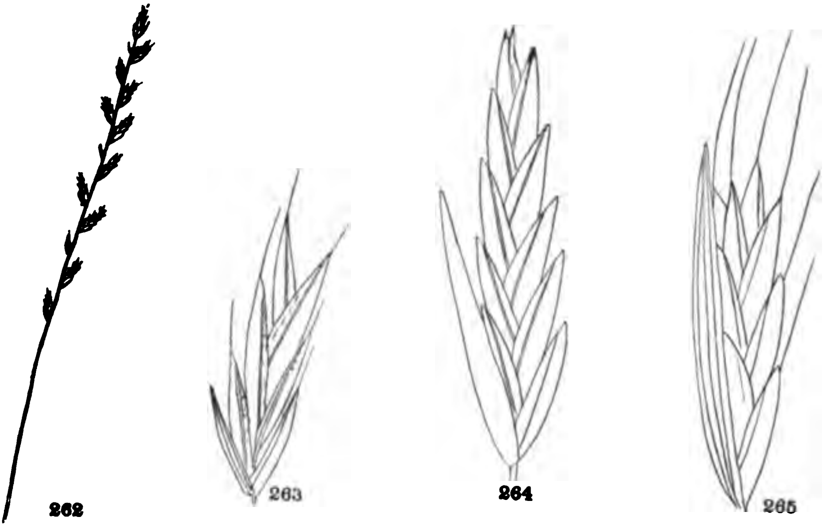
COOK CO. In one vacant lot, Cuyler, Chicago, *Gates,* June, 1905.

58. LOLIUM L.

Rye Grass. Darnel

This genus includes both annuals and perennials introduced from the Old World. The perennial species are cultivated, but frequently escape and establish themselves in certain localities. The inflorescence consists of long spikes. The spikelets are several-flowered and are placed edgewise to the axis. The glume next the axis is wanting, except in the terminal spikelet. The leaves are long and narrow, often showing small projections, called auricles, at the base. The ligules are membranous.

First glume shorter than the spikelet.	
Lemmas awned.	***L. multiflorum***
Lemmas awnless.	***L. perenne***
First glume as long as, or longer than the spikelet.	***L. temulentum***



Figs. 262–265.—262, *L. multiflorum,* inflorescence; 263, *L. multiflorum,* spikelet; 264, *L. perenne,* spikelet; 265, *L. temulentum,* spikelet

Lolium multiflorum Lam.

Italian Rye Grass. Awned Ray Grass (Figs. 262 and 263)

Lolium italicum, Flagg '78, 282.

Culms tufted, erect, 2 to 3 feet tall, the upper part rough; sheaths and leaves smooth, the latter 4 to 8 in. long, 3 to 7 mm. wide; spikelets 10- to 20-flowered, 15 to 20 mm. long; lemmas 7 to 8 mm. long, and awned.

This species is a perennial and a very rapid grower. It forms a dense turf, succeeding best in moist situations. It was introduced for hay, but has been used in making lawns in some parts of the country. The seed is an ingredient of most lawn mixtures.

MACON CO. Decatur, *Clokey* in 1898. PEORIA CO. Peoria, *McDonald,* July, 1903. WABASH CO. Without locality, *Shearer,* July, 1915.

Lolium perenne L.

Perennial Rye Grass (Fig. 264)

Culms tufted, erect, smooth, 1 to 3 feet tall; sheaths smooth; ligule less than 1 mm. long; blades flat, 2 to 5 inches long, 2 to 4 mm. wide, sometimes rough; spikelets 5- to 10-flowered, 8 to 12 mm. long; lemmas awnless.

This species is a perennial, closely related to *L. multiflorum,* and is also used in lawns, meadows, and pastures. The auricles on the leaves are usually pronounced.

CHAMPAIGN CO. Without locality, *Burrill,* June, 1878; Urbana, *Seymour,* July, 1880. CHRISTIAN CO. Taylorville, *Andrews.* COOK CO. Chicago, *Miller,* June, 1914. PEORIA CO. Peoria, *Brendel.*

Lolium temulentum L.

Darnel (Fig. 265)

Culms 2 to 4 feet tall, smooth; sheaths smooth; blades 4 to 10 inches long, 2 to 6 mm. wide, rough on the upper surface; spikelets 4- to 8-flowered, 10 to 18 mm. long, the glumes longer than the spikelets; lemmas sometimes awned.

This species is found in waste places and often becomes a troublesome weed. It was formerly supposed to be poisonous. Now it is said that the poison is due to the presence of a fungus in the fruit.

CHAMPAIGN CO. Urbana, *Seymour,* June, 1878. MENARD CO. Athens, *Hall* in 1861.

59. **AGROPYRON** Gaertn.

Wheat Grass

These grasses are characterized by the spiked type of inflorescence, as in Lolium, from which they differ in having the spikelets placed flat against the axis. The spikelets are 3- to many-flowered. The leaves are usually flat with short, thick ligules. Most of the species have long, running rootstocks. All the species are perennials, and all but one, *A. repens,* are native to this country.

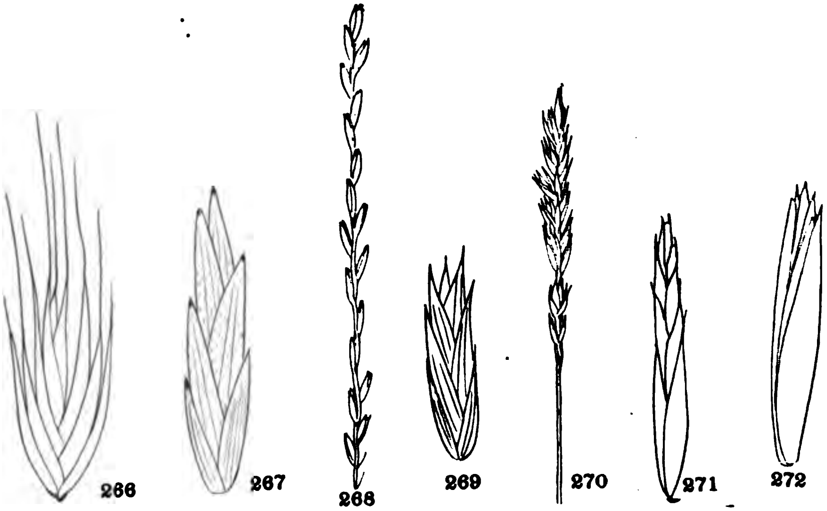
a. Lemmas densely hairy. *A. dasystachyum*
aa. Lemmas not hairy.
  b. Glumes scabrous on the nerves and margins; leaves rough on both surfaces, never pubescent; creeping rootstocks wanting.
    c. Lemmas awned, the awns about twice the length of the lemmas; leaves flat, usually not more than 4 mm. wide; spike very narrow and slender, spikelets not crowded. *A. caninum*
    cc. Lemmas awnless; leaves less than 4 mm. broad and usually rolled; spike rather broad, spikelets crowded. *A. tenerum*
  bb. Glumes smooth, except on the midnerve; leaves never rough on both surfaces; creeping rootstocks present.
    c. Glumes strongly nerved; leaves broad, flat, finely nerved, pubescent on the nerves above, smooth beneath. *A. repens*
    cc. Glumes faintly nerved; leaves narrow, involute, very coarsely nerved, rough above, smooth beneath. *A. smithii*

Agropyron caninum (L.) Beauv.

Awned Wheat Grass (Fig. 266)

Triticum caninum, Vasey '61, 671; Patterson '76, 51; Flagg '78, 282; Brendel '87, 88. *Agropyron caninum,* Higley and Raddin '91, 147; Sherff '12, 420; Sherff '13, 595.

Culms erect, 1 to 3.5 feet tall; sheaths smooth; blades flat, rather thin, rough; spike slightly nodding; spikelets 3- to 6-flowered, 12 to 15 mm. long, exclusive of awns; lemmas 8 to 10 mm. long.



Figs. 266–272.—266, *A. caninum*, spikelet; 267, *A. dasystachyum*, spikelet; 268, *A. repens*, inflorescence; 269, *A. repens*, spikelet; 270, *A. smithii*, inflorescence; 271, *A. smithii*, spikelet; 272, *A. tenerum*, spikelet

This species is found in cultivated ground and meadows. It appears to be rare in Illinois.

ILLINOIS SPECIMENS: Without locality, *Vasey*. MCHENRY CO. Ringwood, *Vasey*.

Agropyron dasystachyum (Hook.) Scribn.

Northern Wheat Grass (Fig. 267)

Culms erect, smooth, 1 to 4 feet tall; sheaths smooth; blades narrow, usually involute; spikelets 4- to 8-flowered, 10 to 20 mm. long; lemmas 9 to 12 mm. long, densely pubescent.

This species is found in sandy places. It belongs to the northern flora but may be found on the shores of Lake Michigan and northward.

DU PAGE CO. C. and N. W. Railway west of Turner, *Moffatt*, June, 1897.

Agropyron repens (L.) Beauv.

Couch Grass. Quitch Grass. Quick Grass (Figs. 268 and 269)

Triticum repens, Lapham '57, 586 (Plate 3, Fig. 3); Vasey '61, 671; Babcock '73, 97; Patterson '76, 51; Flagg '78, 282; Brendel '87, 88. *Agropyron repens*, Higley and Raddin '91, 146; Huett '97, 131.

Culms erect, 1 to 4 feet tall, smooth; sheaths smooth, the lower sometimes pubescent; blades usually flat, rough, and usually sparsely pubescent above; spikelets about 5-flowered, 10 to 15 mm. long; lemmas about 10 mm. long, strongly nerved, often rough, usually terminating in a short awn.

This grass is exceedingly common in fields, especially among cultivated crops, along roadsides, and in waste places. The internodes of the creeping rootstock are bright greenish yellow. Joints of the rootstock will start new plants, making the species an exceedingly hard one to eradicate amongst cultivated crops. It may be destroyed by thoro and persistent cultivation, exposing the rootstocks to the sun. It may also be destroyed by plowing it under in the fall, if it is covered by a depth of six or seven inches of soil.

ILLINOIS SPECIMENS: Without locality, *Vasey*. CHAMPAIGN CO. Urbana, *Seymour*, June, 1880; Urbana, *Clinton*, June, 1897; Urbana, *Waite*, July, 1886. CHRISTIAN CO. Taylorville, *Andrews*. COOK CO. Chicago, *Babcock*, June, 1874; Evanston, *Shipman*, July, 1875; Woodlawn, Chicago, *Lansing*, June, 1898. DU PAGE CO. Naperville, *Umbach*, June, 1898. FULTON CO. Without locality, *Pepoon*. JO DAVIESS CO. Without locality, *Pepoon*. KANKAKEE CO. Kankakee, *Reecher*, July, 1908. MCHENRY CO. Ringwood, *Vasey*. PEORIA CO. Peoria, *McDonald*, July, 1897. Princeville, *V. H. Chase* 1463. STARK CO. Wady Petra, *V. H. Chase*, June, 1907. WABASH CO. Mt. Carmel, *Schneck*, July, 1895.

Agropyron smithii Rydb.

Blue-joint. Western Wheat Grass (Figs. 270 and 271)

Culms stiff, erect, smooth, 1 to 5 feet tall; sheaths smooth; blades bluish green, rough, becoming involute, 4 to 8 mm. long, 4 to 6 mm. wide; spikelets 7- to 13-flowered, 12 to 20 mm. long; lemmas awn-pointed, faintly nerved.

This species is found on the western prairies in alkali soil and is rather common here along railway tracks. It is not a weed like *A. repens*. It can be distinguished from that species by its blue-green color and more densely flowered spikelets.

ILLINOIS SPECIMENS: Without locality, northern Illinois, *Brendel;* Romeo, *Umbach*, June, 1898. JO DAVIESS CO. Hanover, *Gleason* and *Gates* 2599. PEORIA CO. Peoria, *McDonald*, July, 1901 and 1903. STARK CO. Wady Petra, *V. H. Chase* 653, 1518. WILL CO. Joliet, *Skeels* 323; Mokena, *Hill* 15 in 1910.

Agropyron smithii molle (S. and S.) Jones.—This variety is softly pubescent, thus differing from the species.

DU PAGE CO. West Chicago, *Umbach*, June, 1897.

Agropyron tenerum Vasey

Slender Wheat Grass (Fig. 272)

Culms erect, stiff, smooth, 1.5 to 3 feet tall; sheaths smooth; blades flat or involute when dry, rough, 3 to 10 inches long, 2 to 4 mm. wide; spikelets 3- to 5-flowered; lemmas 10 to 12 mm. long, awned or awn-pointed, rough on the margin and toward the top.

This species has no running rootstocks. It is found mostly in dry soil, where it grows in large bunches.

COOK CO. Chicago, *A. Chase* 1132. STARK CO. South of Wady Petra, *V. H. Chase*, 1161.

Agropyron violaceum.—This species is reported by Huett ('97, 131), but no specimens have been seen.

60. HORDEUM L.

Barley

In this genus the inflorescence consists of terminal spikes, the spikelets in groups of three at each joint of the axis. The axis of the spike disjoints with the spikelets attached to the joints. The central spikelet of the group bears perfect florets, but the two lateral ones may be reduced to awns. In cultivated barley we have the two-rowed variety when only the middle spikelet of each group is perfect, and the six-rowed when all are perfect. The glumes are often reduced to awns and together with the sterile lateral spikelets form a cluster of awns below the spikelet. The leaves are flat, usually with well-developed membranous ligules. Besides the cultivated barley, *H. vulgare,* four other species are found in the state, two of which are pernicious weeds.

Spikes slender, not over 3 inches long, the awns of the spikelets not over 15 mm. long.
  Glumes modified into slender awns. *H. nodosum*
  Glumes narrow, broadened in the middle, awn-pointed. *H. pusillum*
Spikes rather stout, with awns 20 to 60 mm. long.
  Awns 30 to 60 mm. long, making a spike about as wide as long; spikelets 1-flowered. *H. jubatum*
  Awns 20 to 35 mm. long, the width of the spike less than one-third its length; spikelets 2-flowered, with often a rudiment of a third. *H. pammeli*

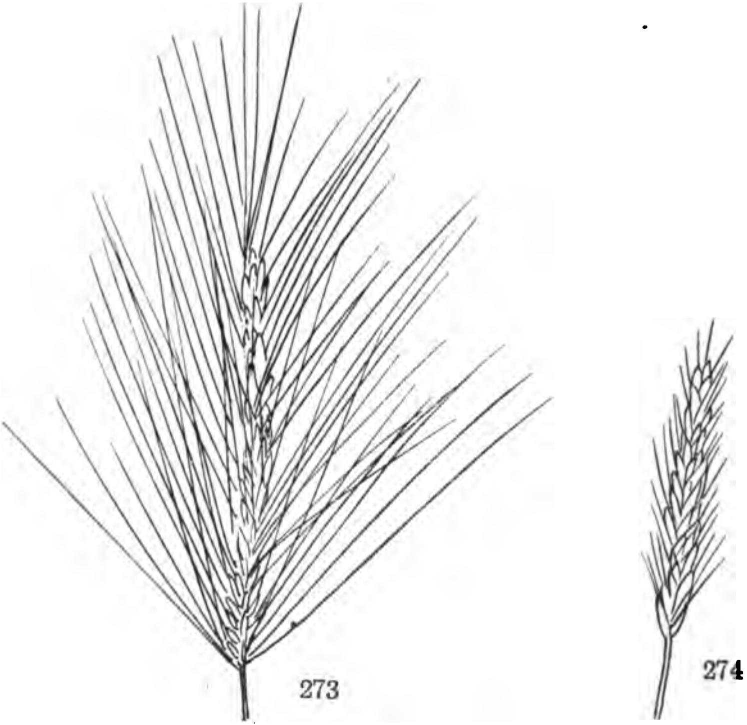
Hordeum jubatum L.

Squirrel-tail Grass (Figs. 273 and 275)

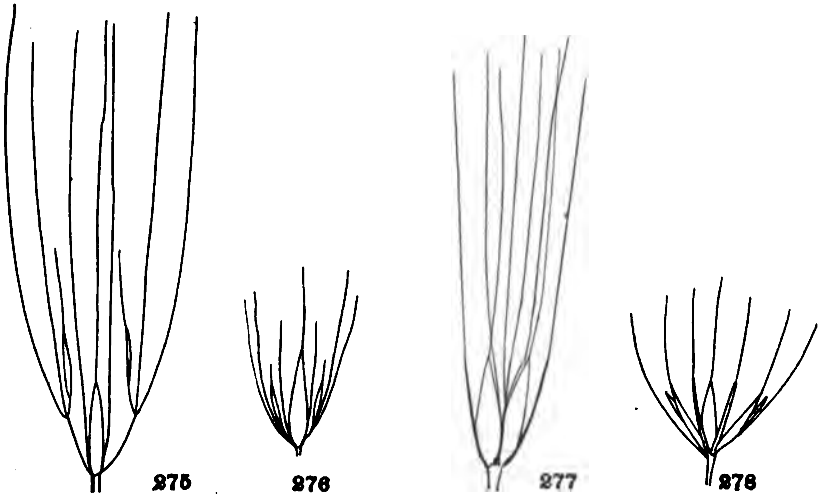
Lapham '57, 547, 586 (Plate 3, Fig. 9); Babcock '73, 97; Patterson '76, 51; Flagg '78, 282; Brendel '87, 64; Higley and Raddin '91, 147; Huett '97, 131; Sherff '13, 595.

Culms in large bunches, 6 inches to 2 feet tall, usually erect, sometimes bent at base, the spikes nodding; sheaths smooth; blades 1 to 5 inches long, 2 to 4 mm. wide, rough; spike 2 to 4 inches long; spikelets in threes, the lateral ones imperfect and reduced to 1 to 3 spreading awns; glumes of the perfect spikelets awn-like, and spreading; lemmas 6 to 8 mm. long, awned; awns of the spikelets all long, slender, and rough.

This species is a biennial and in Illinois often a winter annual. It is one of the worst weeds of the state, not only because it crowds out useful plants, but because the awns are very troublesome to live stock. Any scheme of cultivation that prevents its ripening seed will control it. It is, however, more apt to come up in pastures and waste places which cannot well be cultivated, and as it ripens a large number of seeds, it may spread very rapidly.



Figs. 273–274.—Inflorescences: 273, *H. jubatum;* 274, *H. pusillum*



Figs. 275–278.—Groups of spikelets; 275, *H. jubatum;* 276, *H. nodosum;* 277, *H. pammeli;* 278, *H. pusillum*

CHAMPAIGN CO. Champaign, *Gibbs,* Oct., 1898; Champaign, *Clinton,* Sept., 1895; Urbana, *Seymour,* June, 1880. CHRISTIAN CO. Taylorville, *Andrews.* COOK CO. Woodlawn, Chicago, *Lansing,* June, 1898; Jackson Park, Chicago, *Clark,* June, 1903; Willow Springs, *Grassley,* July, 1876; Lake Forest, *Jensen* in 1895; Evanston, *Shipman;* Evanston, *Johnson,* Sept., 1886; Chicago, *Vasey;* Chicago, *Holton,* Aug., 1850. DU PAGE CO. Hinsdale, *Smith,* Sept., 1902; Naperville, *Umbach,* June, 1898. FULTON CO. Without locality, *Pepoon.* JO DAVIESS CO. Without locality, *Pepoon* 25. KANE CO. Elgin, *Sherff,* 1799. KANKAKEE CO. Kankakee, *De Selm,* June, 1913. LAKE CO. Rockefeller, *Gates,* July, 1907. PEORIA CO. Peoria, *McDonald.* STARK CO. Wady Petra, *V. H. Chase* 72. VERMILION CO. Muncie, *Mosher,* May, 1914. WINNEBAGO CO. Fountaindale, *M. S. Bebb.*

Hordeum nodosum L.

Meadow Barley (Fig. 276)

Hordeum pratense, Patterson '76, 51; Flagg '78, 282; Brendel '87, 64; Huett '97, 131.

Culms sometimes decumbent, 6 inches to 2 feet tall; sheaths smooth; blades rough, 1 to 5 inches long, 1 to 4 mm. wide; spikes 1 to 3 inches long; spikelets mostly in threes and all of the glumes reduced to awns; lemma of the perfect spikelet 6 to 8 mm. long, the awns from 6 to 12 mm. long.

This species is often confused with *H. pusillum* by collectors, as it has the same general appearance altho it is usually a little taller. The character of the glumes is sufficient to separate them. *H. nodosum* is apparently rare in Illinois. It is found in meadows and waste places.

CHRISTIAN CO. Taylorville, *Andrews.* HENDERSON CO. Oquawka, *Patterson,* June, 1872. LA SALLE CO. Utica, *Umbach,* May, 1906.

Hordeum pammeli Scribn. and Ball

(Fig. 277)

Culms erect, or bent at base, 2 to 3.5 feet tall; sheaths smooth; blades 6 to 8 inches long, 5 to 8 mm. wide, rough, acuminate; spikes nodding, 3 to 7 inches long; spikelets in threes, all perfect, the middle spikelet 2-flowered; lemmas 7 to 8 mm. long; glumes modified into slender awns.

This species closely resembles cultivated barley. It is a perennial found on damp prairie soil or along roadsides.

STARK CO. Near Wady Petra, *V. H. Chase* 1467, 1525, 1529.

Hordeum pusillum Nutt.

Little Barley (Figs. 274 and 278)

Engelmann '44, 104; Lapham '57, 547, 587; Gleason '10, 149.

Culms erect, in small tufts, 4 to 16 inches tall; sheaths smooth; blades 1 to 2.5 inches long, 1 to 3 mm. wide, rough; spikes .5 to 3 inches long; spikelets in threes, the lateral ones imperfect; glumes of all spikelets narrow and produced into slender awns; lemma of perfect spikelet 6 to 8 mm. long, awned.

This species is usually a winter annual in Illinois and is becoming increasingly abundant over nearly all parts of the state. It is spreading rapidly along the railroad tracks and other waste places, growing in soil in which other plants grow with difficulty. Among cultivated crops it is easily controlled, as it is an annual and may be destroyed by preventing the formation of seed. In pastures and along roadsides its increase is alarming, as it drives out the better grasses.

ILLINOIS SPECIMENS: Without locality, *Vasey;* Bear Creek, *Mead,* June, 1842. CHAMPAIGN CO. Urbana, *Seymour,* May, 1880; Champaign, *Mosher,* May, 1914. Glover, *Gates* 1546. COOK CO. Englewood, *Derr,* May, 1905. EFFINGHAM CO. Edgewood, *Bartley,* June, 1898. HENDERSON CO. Oquawka, *Patterson* 778. MARION CO. Without locality, *Lapham* in 1857; without locality, *Bebb* in 1860. MENARD CO. Athens, *Hall,* June, 1864. PEORIA CO. Peoria, *McDonald,* June, 1888; Peoria, *Brendel.* PIATT CO. White Heath, *Mosher,* May, 1914. ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase* 588, 1441. VERMILION CO. Muncie, *Mosher,* May, 1914. WABASH CO. Lucas Prairie, *Schneck,* May, 1880; Mt. Carmel, *Schneck,* June, 1879. WILL CO. Joliet, *Hill,* June, 1907; Joliet, *Skeels,* June, 1904.

61. ELYMUS L.

Wild Rye

These grasses have dense terminal spikes, which are usually slightly nodding, and flat leaves. The spikelets are 2- to 6-flowered and are usually in pairs in alternate notches of the axis. The lemmas are awned or awn-tipped. The glumes are usually narrow, sometimes reduced to awns. The spikelets are placed flat against the stalk, and both glumes are at the front of the spikelet. The species are all native.

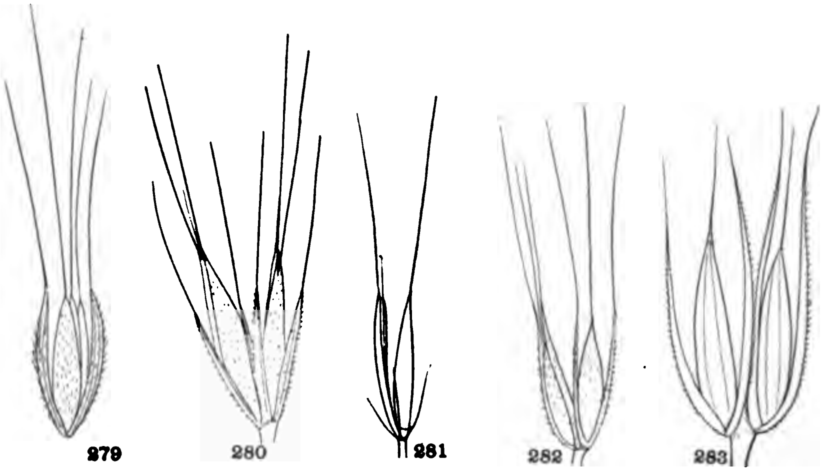
a. Glumes reduced to short, weak awns, the lemmas much longer. *E. diversiglumis*
aa. Glumes not reduced to awns, nearly or quite as long as the lemmas.
  b. Lemmas awned.
    c. Glumes narrow, 1 mm. or less wide, spikelets usually covered with long, fine hairs. *E. striatus*
    cc. Glumes always 2 mm. or more in width.
      d. Glumes strongly bowed out at the base, hardened and yellow for about 2 mm.; spikes usually included in the inflated upper sheaths. *E. virginicus*
      dd. Glumes not strongly bowed out at the base, occasionally hardened and pale; spikes not included in the inflated upper sheaths.
        e. Glumes hardened at base; yellowish for 1 or 2 mm.; spikes stiff and erect. *E. australis*
        ee. Glumes not hardened at base and of the same color thruout; spikes nodding. *E. canadensis*
  bb. Lemmas awnless. *E. arenarius*

Elymus arenarius L.

Culms stout, 2 to 4 feet tall, from long, creeping rootstocks; leaves glabrous; blades involute at tip, the lower 8 to 12 inches long and crowded at the base, the upper shorter; spike stiff, 4 to 6 inches long, densely flowered; spikelets 3- to 7-flowered, 25 to 30 mm. long; glumes and lemmas pointed, covered with short, soft pubescence, sometimes glaucous.

The plants of this species are reed-like. They are found in sandy places along the northern Atlantic coast and the shores of the Great Lakes. The only specimen seen by the writer was found too late to include a figure of the spikelet, but it is very easily recognized and not likely to be confused with any of the other species.

COOK CO. Wilmette, *Killip,* June, 1916.



Figs. 279–283.—279, *E. australis,* spikelet; 280, *E. canadensis,* two spikelets; 281, *E. diversiglumis,* two spikelets; 282, *E. striatus,* two spikelets; 283, *E. virginicus,* two spikelets

Elymus australis Scribn. and Ball

Southern Wild Rye (Fig. 279)

Culms stout, 3 to 5 feet tall; sheaths coarsely hairy; blades 8 to 12 in. long, 10 to 15 mm. wide, rough on both surfaces, sometimes pubescent above; spike 4 to 6 inches long; glumes spreading slightly at base; somewhat thickened, usually pubescent, about 15 mm. long, bearing an awn about as long; lemmas 8 to 10 mm. long, long pubescent, the awns 2.5 to 3 cm. long.

This species is found both in woods and prairies. It differs from *E. canadensis* in having the bases of the glumes thickened, and from *E. virginicus hirsutiglumis* in having a broader, heavier spike and longer awns.

ILLINOIS SPECIMENS: Without locality, *Wolf* in 1882. STARK CO. Original prairie east of Wady Petra, *V. H. Chase* 1238, 1239½ and 1244.

Elymus canadensis L.

Nodding Wild Rye (Fig. 280)

Lapham '57, 547, 588 (Plate 3, Fig. 10); Babcock '73, 97; Patterson '76, 51; Flagg '78, 283; Brendel '87, 64; Higley and Raddin '91, 147; Huett '97, 131; Gleason '10, 149; Gates '12, 355.

Culms stout, 2 to 5 feet tall; sheaths smooth; blades 4 to 12 inches long, 2 to 20 mm. wide, rough; spike 2 to 8 inches long, usually thick and densely flowered; glumes about parallel at base, not hardened; lemmas from almost smooth to very pubescent, 8 to 14 mm. long, the awn 2 to 5 cm. in length.

This is one of the species of the original prairie and is still found abundantly in the state. It prefers sandy soil. The plants are usually glaucous.

ILLINOIS SPECIMENS: Without locality, *Vasey;* Romeo, *Umbach,* July, 1898. CHAMPAIGN CO. Champaign, *Waite;* Seymour, *Tsou,* Oct., 1913. CHRISTIAN CO. Taylorville, *Andrews.* COOK CO. Evanston, *Shipman,* Sept., 1886; Western Springs, *Smith,* Sept., 1902; Salt Springs, Des Plaines region, *Smith,* Sept., 1902. FULTON CO. Without locality, *Pepoon;* Canton, *Wolf.* JO DAVIESS CO. Without locality, *Pepoon* 74 and 1190. HANCOCK CO. Augusta, *Mead* in 1842. LAKE CO. Beach, *Gates* 2879, 2880; Waukegan, *Gleason* and *Shobe* 327. MENARD CO. Without locality, *Hall.* PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* July, 1896. STARK CO. Wady Petra, *V. H. Chase* 1241, 1243, 1550. WABASH CO. Without locality, *Shearer;* Mt. Carmel, *Schneck,* July, 1888; Hanging Rock, *Schneck,* Sept., 1904.

Elymus robustus Scribn. and Smith.—A form of *E. canadensis* with thick, dense, erect spikes not interrupted at base is recognized by some as a distinct species under this name. There are, however, so many intergrading specimens between this form and typical *E. canadensis* that it is difficult to define the two. The following specimens are probably typical of the form:

COOK CO. Chicago, *Babcock.* FULTON CO. Canton, *Wolf.* ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase* 1235. WILL CO. Joliet, *Skeels* 441.

Elymus canadensis glaucifolius (Willd.) Torr.—This name is sometimes given to those specimens covered with a whitish or bluish bloom, but these are really typical *E. canadensis.* It has been mentioned by Patterson ('76, 51), Higley and Raddin ('91, 147), and Huett ('97, 147). The following specimens are typical:

COOK CO. Thornton, *Hill* in 1865. LAKE CO. Beach Area, *Gates* 2880. PEORIA CO. Peoria, *Brendel;* Peoria, *McDonald,* July, 1896. STARK CO. Wady Petra, *V. H. Chase* 1241.1. WABASH CO. Grand Rapids, *Schneck,* July, 1904.

Elymus diversiglumis Scribn. and Ball

(Fig. 281)

Culms 3 to 4 feet high; sheaths smooth; blades 6 to 9 inches long, 6 to 12 mm. wide, rough, ending in a long sharp point; spike 3 to 6 inches long, loosely flowered; lemmas 8 to 10 mm. long, pubescent; the awn 2 to 3 cm. long; glumes reduced to short feeble awns.

This species closely approaches *Hystrix hystrix*, in which the glumes are very minute awns; it does not have pediceled divergent spikelets as in Hystrix.

PEORIA CO. Peoria, *Brendel.*

Elymus striatus Willd.

Slender Wild Rye (Fig. 282)

Lapham '57, 547, 548; Babcock '73, 97; Patterson '76, 51; Flagg '78, 283. *E. strictus* var. *villosus*, Brendel '87, 64. *Elymus striatus*, Higley and Raddin '91, 147; Huett '97, 131; Gleason '10, 49. *Elymus striatus villosus*, Lapham '57, 547, 588; Huett '97, 131. *Elymus propinquus*, Lapham '57, 547.

Culms slender, 1 to 3 feet tall, sheaths smooth or with a few fine, soft hairs; blades 6 to 8 inches long, 4 to 10 mm. wide, rough beneath, slightly pubescent above; spikes 3 to 4 inches long; glumes slightly bowed at base, very narrow, parallel for the greater part of their length; lemma 6 mm. long with an awn 2 to 3 cm. long.

This species is usually found in woods and shady places. It is a more slender, graceful species than either *E. canadensis* or *E. virginicus*.

ILLINOIS SPECIMENS: Without locality, *Vasey;* Hillsgrove, *Holton.* CHAMPAIGN CO. Urbana, *Gibbs*, Oct., 1898; Mahomet, *Seymour*, July, 1884. CHRISTIAN CO. Taylorville, *Andrews.* COOK CO. Without locality, *Lapham.* FULTON CO. Without locality, *Pepoon.* HANCOCK CO. Augusta, *Mead* in 1842. JACKSON CO. Without locality, *Lapham.* JO DAVIESS CO. Without locality, *Pepoon.* KANKAKEE CO. Kankakee, *Hill* 159 in 1873. MCHENRY CO. Algonquin, *Nason*, July, 1878. PEORIA CO. Peoria, *McDonald*, Aug., 1890 and 1900; Peoria, *Brendel.* ST. CLAIR CO. Mascoutah, *Welsch.* STARK CO. Wady Petra, *V. H. Chase* 128 and 1507. WABASH CO. Without locality, *Schneck*, July, 1900; without locality, *Shearer;* Mt. Carmel, *Schneck*, June, 1877 and 1879; near Timberville, *Schneck*, June, 1879.

Elymus striatus arkansanus (Scribn. and Ball) Hitchc.—This variety differs from the species in having smooth or slightly roughened glumes and lemmas.

STARK CO. Near Wady Petra, *V. H. Chase*, June, 1897.

Elymus virginicus L.

Virginia Wild Rye. Terrell Grass. Lyme Grass (Fig. 283)

Lapham '57, 547, 587; Babcock '73, 97; Patterson '76, 51; Flagg '78, 283; Brendel '87, 64; Higley and Raddin '91, 147; Huett '97, 131; Gleason '10, 149; Sherff '13, 595.

Culms stout, 2 to 4 feet tall; sheaths usually smooth, sometimes the upper inflated and inclosing the base of the spike; blades 6 to 12 inches long, 4 to 8 mm. wide, rough; spikes 1.5 to 5 inches long, stiff; glumes smooth, considerably curved or bowed out at base, hardened and yellow for 1 to 2 mm.; lemmas smooth; awn 4 to 18 mm. long.

This species is very common in moist places, particularly along the edges of woods.

ILLINOIS SPECIMENS: Without locality, river banks, *Vasey*. CHAMPAIGN CO. Urbana, *Seymour*, Aug., 1880; Urbana, *Mosher*, Oct., 1915; Mahomet, *Gibbs* and *Clinton*, Oct., 1898. CHRISTIAN CO. Taylorville, *Andrews*. COOK CO. Evanston, *Shipman*, Oct., 1875; Chicago, *Lansing*, July, 1898. FULTON CO. Without locality, *Pepoon;* Canton, *Wolf*. JO DAVIESS CO. Without locality, *Pepoon*. KANKAKEE CO. Kankakee, *Hill* 318 in 1873. MCHENRY CO. Ringwood, *Vasey*. MACON CO. Decatur, *Clokey* in 1898. PEORIA CO. Peoria, *Brendel;* between Laura and Monica, *V. H. Chase* 1824. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase* 1549. TAZEWELL CO. Without locality, *McDonald*, July, 1889. WABASH CO. Without locality, *Schneck*, July, 1879 and 1904; without locality, *Shearer;* Mt. Carmel, *Schneck*, June, 1879 and July, 1900.

Elymus virginicus hirsutiglumis. (Scribn.) Hitchc.—This variety differs from the species in having hairy glumes and lemmas.

ILLINOIS SPECIMENS: Without locality, prairies in northern Illinois, *M. S. Bebb* in 1859. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase* 1231, 1541.

Elymus virginicus submuticus Hook.—In this variety the glumes and lemmas are awnless or awn-pointed and slightly roughened.

ST. CLAIR CO. Mascoutah, *Welsch*.

62. **HYSTRIX** Moench.

This grass has much the general appearance of Elymus, but the spikelets, which are in groups of two or three, have a very short pedicel and at maturity stand horizontally from the stem. The glumes are reduced to short awns and one or both may be wanting. The spikelets are 2- to 4-flowered with long-awned lemmas. The plants are perennial with rather broad, flat leaves and very short thick ligules. A single species is found in Illinois.

Hystrix hystrix (L.) Millsp.

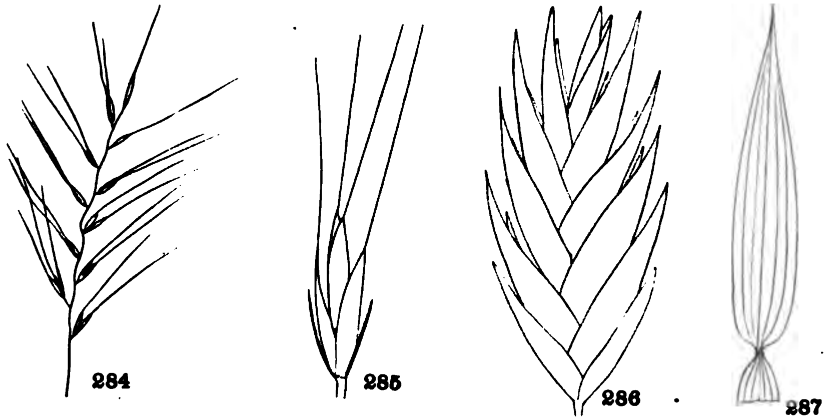
Bottle-brush Grass (Figs. 284 and 285)

Gymnostichum hystrix, Lapham '57, 547, 588 (Plate 3, Fig. 11); Babcock '73, 97; Patterson '76, 51; Flagg '78, 283; Brendel '87, 64. *Asprella hystrix*, Higley and Raddin '91, 147; Huett '97, 131. *Hystrix patula*, Gray's Manual, 7th ed.

Culms unbranched, 2 to 4 feet tall; sheaths smooth; blades rough, 4 to 12 inches long, 8 to 15 mm. wide; spike often included in the upper sheath, 2 to 6 inches long, loosely flowered; spikelets 10 to 15 mm. long, excluding the awns; lemmas often pubescent, their awns 1.5 to 4 cm. long.

This grass is found in moist woods.

CHAMPAIGN CO. Urbana, *Seymour* and *Waite*, July, 1886; Urbana, *Seymour*, June, 1880. COOK CO. Without locality, *Lapham;* Evanston, *Shipman*, Oct., 1875. CHRISTIAN CO. Taylorville, *Andrews*. FULTON CO. Without locality, *Pepoon*. JO DAVIESS CO. Without locality, *Pepoon*. KANKAKEE CO. Kankakee, *Hill* 216 in 1873. KNOX CO. Williamsfield, *V. H. Chase* 1840. LAKE CO. Channel lake, Antioch, *Gleason* and *Shobe*, Aug., 1906; Lake Forest, *Jensen* in 1895. MCHENRY CO. Algonquin, *Nason*, July, 1878. MACOUPIN CO. Carlinville, *Robertson*, Aug., 1880. PEORIA CO. Peoria, *Brendel*. ST. CLAIR CO. Mascoutah, *Welsch*. STARK CO. Wady Petra, *V. H. Chase* 1506; near Spoon river, *V. H. Chase* 622. WABASH CO. Without locality, *Schneck*, July, 1900; without locality, *Shearer*.



Figs. 284–287.—284, *H. hystrix,* inflorescence; 285, *H. hystrix,* spikelet; 286, *A. macrosperma,* spikelet; 287, *A. macrosperma,* leaf showing attachment of blade to sheath

63. ARUNDINARIA Michx.

Cane

These woody grasses of the southern swamps are found along the banks of the rivers in the southern part of the state. The genus is characterized by the perennial, woody culms, also by the blades narrowed into a short petiole at the junction with the sheath. The spikelets are large, flattened, many-flowered, with the lemmas keeled and ending in a sharp point. The plants do not flower every year. The leaves are broad compared with the width and very firm. There are two species of Arundinaria in the country and both have been reported from Illinois. These are *A. macrosperma* and *A. tecta,* known as giant cane and small cane. These are distinct species, but only one, *A. macrosperma,* occurs in Illinois, the other being confined to the Atlantic coast. Lapham reports that the culms of *A. macrosperma* reach a height of thirty or forty feet in southern Illinois, yet recent specimens of that species collected there are less than two feet tall. Similar small specimens of *A. macrosperma* have doubtless been incorrectly referred to *A. tecta.*

Arundinaria macrosperma Michx.

Large Cane. Giant Cane (Figs. 286 and 287)

Michaux '03, 74; Lapham '57, 547, 584, (Plate 3, Fig. 5); Patterson '76, 51; Flagg '78, 282. *A. tecta,* Patterson '76, 51; Flagg '78, 282.

Culms woody, 1.5 to 40 feet tall, branched near the top; sheaths ciliate on the margins, otherwise glabrous; leaves lanceolate, sometimes rough, 3 to 12 inches long, the largest 20 to 30 mm. wide; inflorescence on the old wood; spikelets 35 to 60 mm. long.

This species is still found in large masses in some of the swamps of the southern states, where they are known as cane-brakes.

ILLINOIS SPECIMENS: Without locality, southern Illinois, *Vasey;* without locality, *Lapham.* JACKSON CO. Makanda, *Seymour,* Aug., 1880. ST. CLAIR CO. Mascoutah, *Welsch.* WABASH CO. Banks of Wabash river, *Schneck* in 1879, June, 1905; July, 1904; Mt. Carmel, *Patterson,* Sept., 1877; Mt. Carmel, *Schneck,* June, 1900.

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UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

BULLETIN No. 206

FIELD EXPERIMENTS IN SPRAYING APPLE ORCHARDS IN 1913 AND 1914

BY
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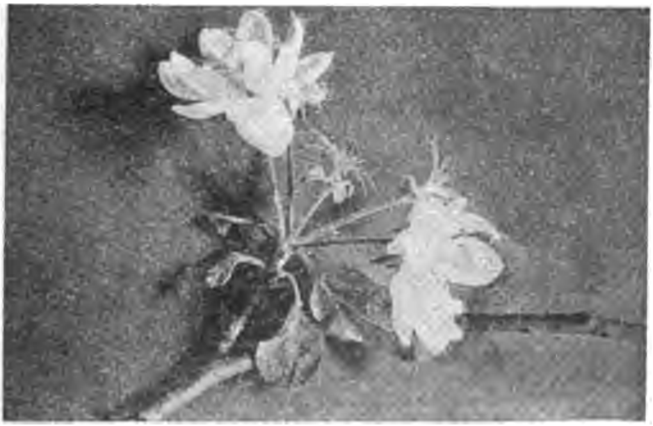

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FIELD EXPERIMENTS IN SPRAYING APPLE ORCHARDS IN 1913 AND 1914

INTRODUCTION

By B. S. PICKETT, Assistant Chief in Pomology

Objects of Field Experiments in Spraying Apple Orchards in 1913 and 1914

In view of the exhaustive investigations already made by the Department of Horticulture in spraying for the control of insects and diseases attacking the apple,[1] it seems advisable to explain the necessity for further experiments in spraying.

No single operation in apple growing yields such immediate and large returns for the money and time invested as spraying. In fact, it is a rare season in Illinois when unsprayed apples are marketable, except for cider and evaporating purposes. The extreme importance of the operation, in itself, is therefore sufficient cause for unremitting experimental efforts to make it more and more effective and less and less costly. New sprays are constantly being placed on the market by enterprising firms dealing in spraying materials. New forms of standard insecticides and fungicides, whose merits and faults call for investigation, are introduced annually. Some of the effects of the standard sprays are not yet fully understood, as, for example, Bordeaux russet, yellowing of the leaves following the use of Bordeaux, and lime-sulfur burn. The efficiency of the standard sprays varies in different seasons, and only the cumulative data of many years of experimental work seem likely to afford records sufficient to permit a conclusive coordination between climatic conditions and the effects of the sprays. Methods of application, including amounts, pressures, character of agitation, and machinery, are not yet perfect; each season's experiments show a need for further tests along these lines.

The field experiments in spraying in 1913 and 1914 included further tests of the effectiveness and relative values of the standard sprays on the control of fungi and insects affecting the apple crop, of several makes and brands of arsenate of lead, certain new and proprietary fungicides, several methods of preparing and using copper ferrocyanide, the effects of varying quantities, pressures, and nozzle openings, the use of Bordeaux for some applications and lime sulfur for the remaining applications in the spray schedule of the same season, the effects of certain special spray practices on the control of codling moth, and the efficiencies of various strengths of lime sulfur.

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[1] The details of these investigations are contained in Bulletins 98, 106, 114, 117, 118, 135, and 185, and popularized in Circulars 112, 120, 136, 137, 159, 160, 171, and 172.

ORGANIZATION

The experimental orchards were located at Neoga in Cumberland county, at Flora in Clay county, and at Griggsville in Pike county. O. S. Watkins conducted the experiments at Neoga, W. A. Ruth, those at Flora, and A. J. Gunderson, those at Griggsville.

STANDARD SPRAYS: FORMULAS AND PREPARATION

Except where noted in connection with the individual experiments, the standard sprays used were prepared according to the following formulas and directions:

Bordeaux.—Eight pounds copper sulfate, 8 pounds freshly slaked lump lime, 100 gallons water. The mixture was prepared by dissolving the copper sulfate in half the total quantity of water used, and mixing the slaked lime with the other half. The diluted solution and the diluted mixture of lime were then poured simultaneously thru a sieve, either into the mixing tank or directly into the spray tank.

Lime Sulfur, Commercial, for Summer Sprays.—Eight pounds of sulfur in 100 gallons of spray (3 gallons commercial concentrated lime sulfur to 97 gallons of water, or 3 gallons commercial concentrated lime sulfur in 100 gallons of the dilute summer spray).

Lime Sulfur, Commercial, for Dormant Spray.—Twenty-nine to 30 pounds of sulfur in 100 gallons of spray (11 gallons commercial concentrated lime sulfur to 89 gallons of water, or 11 gallons commercial concentrated lime sulfur in 100 gallons of spray).

Lime Sulfur, Homemade, for Summer Sprays.—Eight pounds of sulfur in 100 gallons of spray (5½ gallons stock solution homemade lime sulfur to 94½ gallons of water, or 5½ gallons stock solution homemade lime sulfur in 100 gallons of spray).

Lime Sulfur, Homemade, for Dormant Spray.—Twenty-nine pounds of sulfur in 100 gallons of spray (20 gallons stock solution homemade lime sulfur to 80 gallons of water, or 20 gallons stock solution homemade lime sulfur in 100 gallons of spray).

Stock Solution, Homemade Lime Sulfur.—One hundred pounds of sulfur, 50 pounds of lime, water to make 66 gallons.[1] Homemade lime sulfur was prepared by placing in a large kettle 15 gallons of water and 50 pounds of good lime, free from air-slaked particles. When the lime was slaking vigorously, 100 pounds of powdered sulfur was poured in and mixed thoroly with the lime. Sufficient water was added gradually to prevent the lime from drying out during the process of slaking. As soon as the lime was thoroly slaked and the sulfur thoroly mixed, enough water was added to bring the total volume to 66 gallons or a little more. Boiling was continued for 30 to 45 minutes, water being added from time to time to keep the volume at 66 gallons. By following this method it was found possible to get the maximum amount of sulfur into solution. The boiling was done in large iron kettles heated over simple outdoor fireplaces or in 75-gallon feed cookers.

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[1] Illinois formula.

Arsenate of Lead.—Four pounds of paste arsenate of lead in 100 gallons of water, Bordeaux, or lime sulfur. The arsenate of lead was worked up with a small quantity of water into a mixture that would pour readily and mix evenly with the water or fungicide when subjected to the action of the agitator in the spray tank.

TIMES OF APPLICATION

The various applications are designated as follows: dormant-tree spray, first, second, third, and fourth summer sprays, and extra sprays. The dormant-tree, or winter, spray is applied between the falling of the leaves in autumn and the swelling of the buds in spring. Its primary function is the destruction of scale insects. The first summer spray is applied between the bursting of the cluster buds and the opening of the blossom buds. The application of the second summer spray is begun as soon as most of the petals have fallen. It is followed in about ten days by the third application. The time of the later applications varies, depending on the purposes for which they are given. The exact dates of the applications in these experiments are given with each report.

RECORDS

The records of these experiments include data of insect and fungous attacks on both fruit and foliage and of the amount and character of spray injury, percentages of the various grades of fruit, and observations of prevailing conditions of weather. Dropped apples were examined at intervals thruout the season, and at harvesting time both dropped and picked apples were examined for evidences of disease and insect injury, the observations being tabulated for comparative study. Frequent observations of the effectiveness of the sprays in controlling insects and fungi attacking the foliage, or of their being in themselves the cause of injury, were also recorded. Weather observations were recorded in the form of daily maximum and minimum temperatures, temperatures at stated hours, rainfall, cloudiness, and direction of the wind.

ARRANGEMENT OF SUBJECT MATTER

The method of presenting the data obtained in the spraying experiments in 1913 and 1914 is similar to that used in Bulletin 185, which gives the data recorded during the years 1909-12. A yearly report is made by each experimenter, giving at length the plan of the experiment, conditions, methods, data, and summary of results. A general summary of all the results for the two years follows. Finally, a series of spraying recommendations is given.

SPRAYING EXPERIMENTS IN 1913 AT NEOGA, CUMBERLAND COUNTY

BY O. S. WATKINS, ASSOCIATE IN HORTICULTURAL CHEMISTRY

OBJECTS

The chief objects of the investigations at Neoga in 1913 were to determine (1) the comparative values of several brands of arsenate of lead, alone and in combination with lime sulfur; (2) the value of a fourth summer spray for the control of second-brood codling moth; and (3) the relation of pressure to Bordeaux injury.

LOCATION AND DESCRIPTION OF ORCHARD

An orchard owned by H. A. Aldrich and Company and situated one-half mile west of the railroad station at Neoga was chosen for these experiments. The 120 acres comprizing the orchard were planted to several different varieties of apples, thereby affording ideal pollinizing conditions. Since the planting of the orchard in 1900, it had received excellent care; hence the trees were in a very healthy condition. Seven acres of Ben Davis trees and five acres of Jonathan trees were selected for experimental purposes. These tracts were divided into plats of four to ten trees each, the various plats being treated differently. Scattered among the plats were certain trees which were not sprayed, and which were reserved for comparison with the sprayed trees. The arrangement of the plats is shown in Fig. 1.

APPARATUS AND MATERIALS

The sprays were prepared according to the methods described on pages 430 and 431. They were applied with a Friend power outfit; unless otherwise stated, a pressure of about 135 pounds was used. A single Friend angle nozzle was used on the tower pole, and a Gould double Mistry, attached to an angle Y, was used on the ground pole.

The brands of arsenate of lead tested were Corona dry, Vreeland powdered, and Grasselli, Hemingway, Sherwin-Williams, and Thomsen pastes.

WEATHER CONDITIONS

The weather conditions for 1913 were far from normal. Early in May a drouth began which continued until late in August. The combined rainfall of May, June, July, and the first three weeks in August was less than four inches, and at no time was there as much

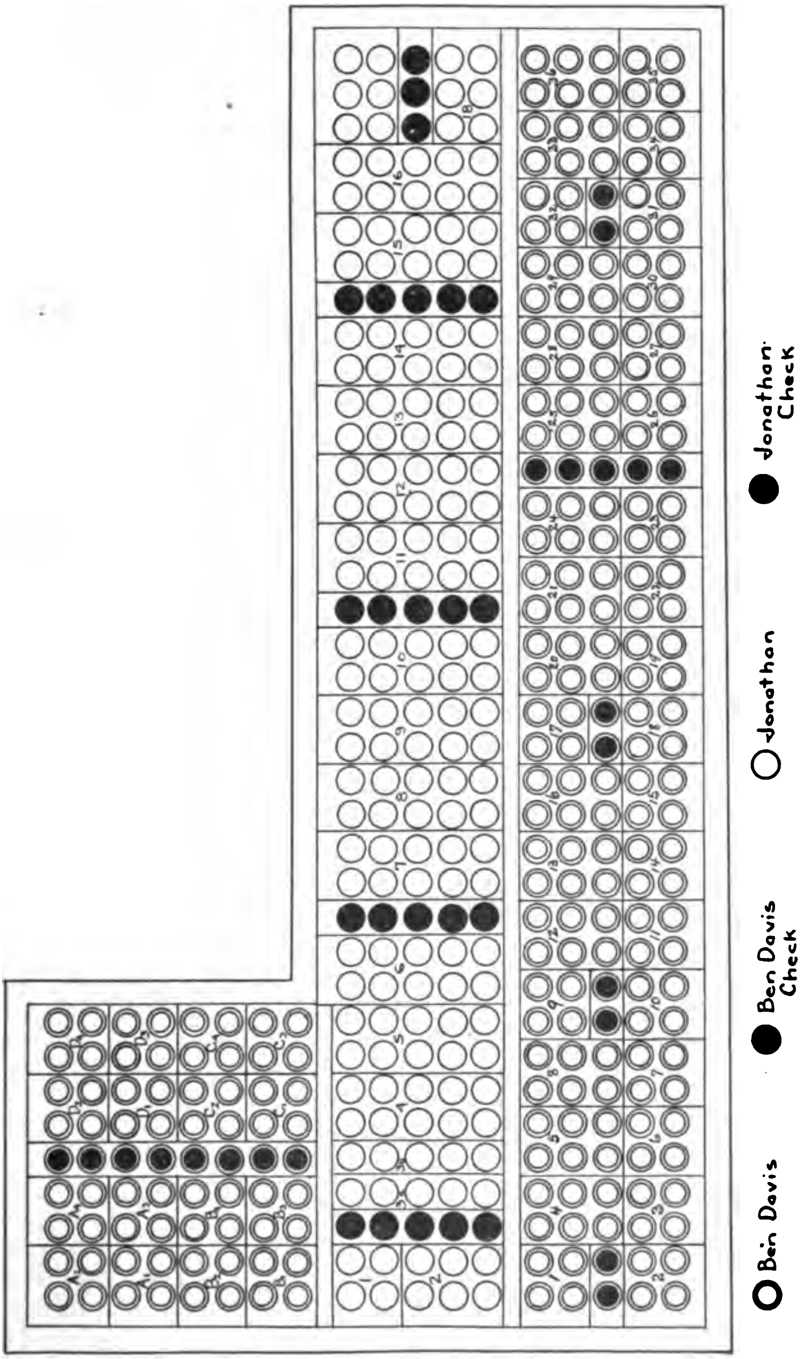

FIG. 1.—PLAN OF PLATS IN ORCHARD OF H. A. ALDRICH AND COMPANY, NEOGA, 1913

as one-half inch in a single rain. The orchard was, therefore, in a very dry condition all summer. Even the spray pond was exhausted during the third application, and water for the remainder of this application and for all of the fourth was hauled from a well in town. On five days in June, eight days in July, seven days in August, and two days in September, the temperature exceeded 100° F. During this dry season no fungous diseases developed; hence the data collected relate chiefly to codling-moth injury.

The trees came into bloom early in May. The bloom of the Jonathan trees was very heavy, but that of the Ben Davis trees was light and scattering. The weather was excellent for pollination, and a very good set of fruit resulted wherever there was good bloom.

SPRAY DATES

The entire orchard was given a winter application of lime sulfur early in April. Three or four summer applications were made upon or near the following dates: April 24, May 12, May 22, and July 8.

TESTS OF VARIOUS BRANDS OF ARSENATE OF LEAD ALONE AND IN COMBINATION WITH LIME SULFUR

These tests were made with the Ben Davis variety on plats of four to six trees each. The plats were treated as shown in Tables 1 and 2. In every case, applications were made on the same day and under conditions as nearly alike as possible.

EFFECT ON FOLIAGE

Little difference was noticed in the appearance of the foliage given the various treatments. As late as September it was impossible to distinguish the unsprayed trees from the sprayed, except by close inspection. Where arsenate of lead alone was used, no spray injury of any kind appeared. Plat 28, sprayed with Vreeland powdered arsenate of lead and lime sulfur, showed a small amount of leaf-burning shortly after the third application, but this resulted in no serious injury to the foliage.

EFFECT ON FRUIT

The fruit from the plats sprayed with arsenate of lead without a fungicide was picked October 14, with the results presented in Table 1. Less than half a crop was harvested; consequently the records obtained may not be considered entirely conclusive. A very severe infestation of codling moth was present; in fact the unsprayed trees showed nearly 100-percent injury. In both the sprayed and the unsprayed plats, the smaller the crop, the greater was the injury. In the plat sprayed with Grasselli arsenate of lead, where less than a bushel of apples per tree was produced, the infestation was severe. The best control was shown in the plat sprayed with Sherwin-Williams arsenate of lead, where the trees yielded considerably more fruit.

TABLE 1.—EFFECTS OF DIFFERENT ARSENATES OF LEAD USED ALONE, ON BEN DAVIS APPLES, IN THE EXPERIMENTS AT NEOGA, 1913

Plat	Treatment	Applications	Picked apples				
			Total No.	Percentage affected by—			
				Codling moth			Russet
				Calyx	Side	Total	
19	4–100 Grasselli arsenate of lead	1, 2, 3	528	3	63	66	0
21	4–100 Sherwin-Williams arsenate of lead.............	1, 2, 3	2310	4	30	34	0
23	2–100 Corona dry arsenate of lead...................	1, 2, 3	2096	1	43	44	0
Check	No treatment...............	None	416	18	80	98	0

Most of the trees sprayed with the various arsenates of lead in combination with lime sulfur produced a half crop or more. This was picked October 14; the results of the examinations are shown in Table 2. The trees in these plats, like those sprayed with arsenate of lead alone, showed a large amount of codling-moth injury; here, also, the degree of injury tended to vary with the yield of fruit. Plat 25, sprayed with 4-100 Corona dry arsenate of lead, and having the largest yield of fruit, showed the least injury from codling moth. Only one plat, that receiving Vreeland powdered arsenate of lead, showed any russet; 9 percent of the fruit from that plat was sufficiently russeted to be graded with the culls.

TABLE 2.—EFFECTS OF DIFFERENT ARSENATES OF LEAD IN COMBINATION WITH LIME SULFUR, ON BEN DAVIS APPLES, IN THE EXPERIMENTS AT NEOGA, 1913

Plat	Treatment	Applications	Picked apples				
			Total No.	Percentage affected by—			
				Codling moth			Russet
				Calyx	Side	Total	
A_1	4–100 Grasselli arsenate of lead with lime sulfur.........	1, 2, 3	1530	5	45	50	0
24	2–100 Corona dry arsenate of lead with lime sulfur....	1, 2, 3	2060	2	49	51	0
25	4–100 Corona dry arsenate of lead with lime sulfur..	1, 2, 3	3571	2	38	40	0
26	4–100 Thomsen triplumbic arsenate of lead with lime sulfur.................	1, 2, 3	1064	5	56	61	0
27	4–100 Hemingway arsenate of lead with lime sulfur.....	1, 2, 3	1800	7	56	63	0
28	2–100 Vreeland powdered arsenate of lead with lime sulfur.................	1, 2, 3	2112	14	50	64	9
Check	No treatment	None	416	18	80	98	0

The results of this experiment, altho hardly consistent, somewhat favor the Grasselli paste and Corona dry arsenates of lead.

VALUE OF A FOURTH SUMMER SPRAY FOR SECOND-BROOD CODLING MOTH

It has been a question among growers whether the second-brood codling moth did sufficient injury to warrant a special application to prevent it. To determine the value of a fourth summer spray, applied early in July, at the proper time to check the attacks of second-brood codling moth, two plats of Ben Davis trees were sprayed as shown in Table 3. Commercial lime sulfur and Grasselli arsenate of lead paste were used.

In order to determine the effect of the spray upon an earlier ripening variety, experiments were also conducted on Jonathan apples, which mature two or three weeks earlier than Ben Davis. Valuable results were secured, for the fruit of this variety was picked before a third brood, which appeared very late in the season, began to work. The treatments for the Jonathan plats are shown in Table 4. Each plat was divided into two sections of five trees each; one section was sprayed three times and the other four times.

EFFECT ON FOLIAGE

No foliage injury of any kind appeared. On the Ben Davis trees the fourth application was visible thru the entire season. On the Jonathan plats, wherever Bordeaux arsenate of lead was used, the spray remained visible longer than where other sprays were applied.

EFFECT ON FRUIT

The Ben Davis plats produced a small crop, which was picked October 15, giving the results presented in Table 3. Here the benefits of the fourth application could not be determined, for a third brood of moths began infesting the apples early in October, upon which the application made in July exerted no influence. This late brood far outnumbered the first and second broods combined.

TABLE 3.—EFFECTS OF SPRAYING FOR SECOND-BROOD CODLING MOTH, ON BEN DAVIS APPLES, IN THE EXPERIMENTS AT NEOGA, 1913

Plat	Treatment	Applications	Picked apples			
			Total No.	Percentage affected by codling moth		
				Calyx	Side	Total
A_1	Lime sulfur arsenate of lead..........	1, 2, 3	1530	5	45	50
A_2	Lime sulfur arsenate of lead..........	1,2,3,4	822	3	50	53
Check	No treatment.......................	None	416	18	80	98

All the Jonathan plats produced a good crop. The fruit was picked September 23, and showed the results presented in Table 4. The fourth application reduced codling-moth infestation from 15 to 47 percent wherever used, thus demonstrating the effectiveness and value of this spray, especially for seasons like that of 1913, when the insect was present in such large numbers. In contrast to the Ben Davis plats, where the fruit was harvested after the appearance of a third brood, the fruit from the Jonathan plats showed the actual degree of control exercised by the sprays on the second brood. Quite a number of apples were cracked, probably as a result of rapid growth caused by the rains which fell just previous to the ripening of the fruit.

TABLE 4.—EFFECTS OF SPRAYING FOR SECOND-BROOD CODLING MOTH, ON JONATHAN APPLES, IN THE EXPERIMENTS AT NEOGA, 1913

Plat	Treatment	Applications	Picked apples				
			Total No.	Percentage affected by—			
				Codling moth			Cracking
				Calyx	Side	Total	
4	Copper ferrocyanide arsenate of lead.................	1, 2, 3	4234	3	29	32	3
	Copper ferrocyanide arsenate of lead................	1, 2, 3, 4	2391	2	15	17	2
7	Lime sulfur arsenate of lead..	1, 2, 3	3739	2	24	26	5
	Lime sulfur arsenate of lead...	1, 2, 3, 4	5067	3	14	17	3
8	Lime sulfur arsenate of lead.. Bordeaux arsenate of lead...	1, 2 3	4050	2	25	27	4
	Lime sulfur arsenate of lead.. Bordeaux arsenate of lead...	1, 2 3, 4	4261	5	18	23	4
12	Bordeaux arsenate of lead..	1, 2, 3	3474	7	27	34	12
	Bordeaux arsenate of lead....	1, 2, 3, 4	5800	6	20	26	6
Check	No treatment.............	None	456	32	52	84	2

NOTE.—Four pounds of Grasselli arsenate of lead paste were added to each 100 gallons of spray. The copper ferrocyanide was made from 2 pounds of copper sulfate dissolved in 50 gallons of water, and 2 pounds of potassium ferrocyanide dissolved in another 50 gallons of water, poured together simultaneously. Commercial lime sulfur and 8-8-100 Bordeaux were used.

EFFECT OF PRESSURE ON BORDEAUX INJURY

In 1905 the Station began an investigation to determine the cause of injury following the use of Bordeaux. It had been noticed that whenever the material was applied with a hand outfit at a pressure of about 100 pounds, there was less injury than when it was applied with a power sprayer, which gave a higher pressure. To gain further information on this point, 8-8-4-100 Bordeaux arsenate of lead was applied to Jonathan trees at the pressures shown in Table 5.

EFFECT ON FOLIAGE

The trees sprayed with Bordeaux arsenate of lead at 125 pounds pressure developed no leaf-yellowing whatever. Those sprayed at a pressure higher than 125 pounds showed a small amount of this injury. In every case, the higher the pressure, the greater was the injury, altho in no plat was it serious. Heretofore Bordeaux injury had been accompanied by wet weather; this was not the case, however, in 1913.

EFFECT ON FRUIT

The trees in these plats yielded a very heavy crop of fruit, which was picked September 24, with the results presented in Table 5. The point of greatest interest in this table is in the russet column. Bordeaux applied at 125 pounds pressure caused no russeting whatever, while all pressures above that caused considerable injury. The extremely high pressures caused no more injury than the 160-pound pressure. The loss of fruit due to cracking was also greater where the higher pressures were used.

TABLE 5.—EFFECTS OF SPRAYING JONATHAN APPLES AT DIFFERENT PRESSURES WITH 8-8-4-100 BORDEAUX ARSENATE OF LEAD, IN THE EXPERIMENTS AT NEOGA, 1913

Plat	Spray pressure	Applications	Picked apples					
			Total No.	Percentage affected by—				
				Codling moth			Russet	Cracking
				Calyx	Side	Total		
9	160 lbs.	1, 2, 3	5192	1	16	17	5	15
	160 lbs.	1, 2, 3, 4	6450	4	14	18	13	14
10	190 lbs.	1, 2, 3	5939	1	20	21	9	10
	190 lbs.	1, 2, 3, 4	5550	1	16	17	9	16
11	225 lbs.	1, 2, 3	1007	4	26	30	7	17
	225 lbs.	1, 2, 3, 4	3157	2	20	22	9	22
12	125 lbs.	1, 2, 3	3474	7	27	34	0	12
	125 lbs.	1, 2, 3, 4	5800	6	20	26	0	6
Check	No treatment.	None	416	18	80	98	0	0

The question as to the necessity of using 200 pounds pressure in spraying for codling moth is apt to come up in this connection. These results show that 225 pounds pressure controlled codling moth very little more efficiently than 125 pounds.

Interesting facts not shown in the table were brought to light by an examination of the dropped apples. Very little codling-moth injury appeared earlier than August 1, even upon the check trees. From August 1 until harvest time the number of drops injured by codling moth rapidly increased. Practically all dropped apples which were picked up under check trees during August and September, showed codling-moth injury. In some of them as many as eight wormholes appeared in a single apple.

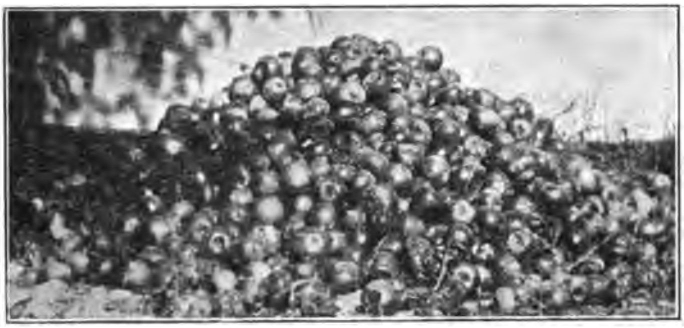

FIG. 2.—2,325 DROPPED APPLES FROM AN UNSPRAYED TREE, NEOGA, 1913

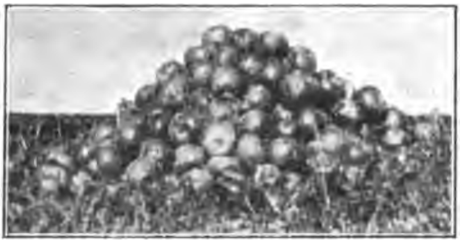

FIG. 3.—203 DROPPED APPLES FROM A PROPERLY SPRAYED TREE, NEOGA, 1913

About September 1, a very heavy drop of apples occurred from the unsprayed trees. This continued for ten days, when it suddenly stopped; very few apples fell from then until picking time. In Fig. 2 are shown 2,325 apples picked up under one unsprayed tree, while in Fig. 3 are shown 203 apples from an adjoining, properly sprayed tree. An examination of these apples revealed the presence of much codling-moth injury.

SUMMARY OF RESULTS AT NEOGA, 1913

1. Differences in the control of codling moth shown in these experiments by the various brands of arsenates of lead are attributed not so much to differences in the chemicals themselves as to unequal conditions of infection, arising chiefly from wide variations in the quantity of fruit borne by the different plats.

2. The powdered arsenates of lead proved very convenient to handle. The Vreeland brand caused a slight injury to the foliage which was not noticed in the plats sprayed with Corona dry.

3. A fourth application of arsenate of lead applied to Jonathan trees to check the ravages of second-brood codling moth was very effective, reducing the injury from this insect several percent wherever used.

4. A fourth application of arsenate of lead applied early in July failed to control third-brood codling moth, which appeared early in October, infesting unpicked apples.

5. The infestation of codling moth was the most serious in the history of the experimental work at Neoga.

6. Arsenate of lead applied at 125 pounds pressure controlled codling moth almost as well as that applied at 225 pounds pressure.

7. Bordeaux applied at 125 pounds pressure caused no injury, while pressures of 160 pounds and higher appeared to cause considerable russeting of the fruit and some foliage injury.

8. A heavy drop of Jonathan apples early in September appeared to have been caused by attacks of codling-moth.

SPRAYING EXPERIMENTS IN 1914 AT NEOGA, CUMBERLAND COUNTY

By O. S. WATKINS

OBJECTS

The investigations at Neoga in 1914 were made to determine (1) the insecticidal efficiency of certain brands of arsenate of lead, alone and in combination with lime sulfur; (2) the fungicidal efficiency of soluble sulfur, atomic sulfur, calcium hyposulfite, copper ferrocyanide, and tuber tonic; (3) the effect of varying the pressure in applying Bordeaux; and (4) the effectiveness of certain standard nozzles. Conditions arising during the season made it possible to obtain information also on the effects of (1) special sprays applied to control delayed broods of codling moth; and (2) banding the trees as a supplementary means of controlling codling moth.

LOCATION AND DESCRIPTION OF ORCHARDS

Two apple orchards were used in carrying on these experiments. The neglected Storer orchard, located one and one-half miles northwest of Neoga, was selected for testing the fungicidal value of certain sprays applied during the dormant season. This orchard, consisting of eleven acres, was about eighteen years old, and was planted to several varieties, including Ben Davis, Winesap, and Willow. For the customary detailed experimental work, fourteen acres of trees were selected from the 120-acre orchard owned by H. A. Aldrich and Company. The experimental blocks consisted of five acres of Black Ben Davis, two acres of Grimes, and five acres of Jonathan trees. These blocks of trees were separated by rows of other varieties which were cared for by H. A. Aldrich and Company. Each block was divided into plats of from five to fourteen trees each. At regular intervals, unsprayed trees were reserved for comparison with the sprayed trees.

APPARATUS AND MATERIALS

The sprays were applied with a Friend power sprayer equipped with a New Western motor pump and 100-gallon tank. The powerful engine and large-capacity pump insured a sufficient range of pressure for all experiments, while the small tank proved convenient and efficient for applying the comparatively small amounts of spray required for each plat.

In the test of the effectiveness of various types of nozzles Bordeaux, Morrel and Morley Eclipse, Friend, and Gould Mistry nozzles were compared. In all other tests a single Friend angle nozzle was used on the tower pole and a double Gould Mistry nozzle on the ground pole. The standard spraying materials were prepared according to the directions given on pages 430 and 431, with the exceptions noted in connection with the individual experiments. A constant pressure of 135 pounds was used in all experiments except those on comparisons of pressures.

WEATHER CONDITIONS

The weather conditions of 1914 were hardly normal. There were several rains during the summer, but other conditions were such as to counteract much of the good they might have done. In May, three rains gave a precipitation of seven-eighths inch; in June, six rains gave three inches; in July, six rains gave one and one-fourth inches; in August, eight rains gave five inches; and in September, four rains gave three inches. During June there were six days when the thermometer passed 100° F., and during July there were eleven such days. The general character of the season was hot and dry, in spite of the fact that there was a reasonable total precipitation.

Full bloom was recorded from April 28 to May 1. There was very heavy bloom on the Ben Davis and the Black Ben Davis trees, a fair bloom on the Grimes, and a scattering bloom on the Jonathan trees. Excellent weather for pollination prevailed, and the blooms set well.

SPRAY DATES

All plats in the Aldrich orchard were given an application of winter-strength lime sulfur early in April. Four to six later applications were made upon or near the following dates: April 25, May 5, May 18, June 14, July 8, and September 1. The applications on June 14 and September 1, made especially to combat the ravages of codling moth, were in addition to the usual schedule.

INSECTICIDAL EFFICIENCY OF CERTAIN BRANDS OF ARSENATE OF LEAD USED ALONE AND IN COMBINATION WITH LIME SULFUR

Each plat in this group consisted of five trees of the Black Ben Davis variety. All plats were sprayed under conditions as nearly alike as possible. The brands of arsenate of lead tested and the treatments given are presented in Tables 6 and 7. Owing to the late arrival of the material, Plat 13, sprayed with Grasselli powdered arsenate of lead, and Plat 19, sprayed with the same material and lime sulfur, did not receive the first, or cluster-bud application.

EFFECT ON FOLIAGE

Careful observations disclosed no spray injury on any of the plats. Of the arsenates of lead used alone, Corona dry and Sherwin-Williams dry appeared to be the most adhesive.

EFFECT ON FRUIT

The fruit from the plats sprayed with arsenate of lead alone was picked and examined October 16 and 17, with the results presented in Table 6. The character of the codling-moth infestation was so severe as to give an excellent opportunity for testing the effectiveness of poison sprays in its control. The infestation of the two check plats was 84 and 97.3 percent, respectively. Many of the unsprayed apples were entered by several larvæ; had the individual larvæ entrances been counted instead of the number of apples attacked, the infestation would have been represented by several hundred percent. In view of the severe infestation, all the treatments, except those of Plats 12 and 13, gave a satisfactory control of codling moth, the infestation ranging from 2.1 to 6.8 percent. On Plats 12 and 13, sprayed with Grasselli paste and powdered arsenates of lead, respectively, the codling-moth infestation amounted to 16 and 31.7 percent. Grasselli

TABLE 6.—EFFECTS OF VARIOUS BRANDS OF ARSENATE OF LEAD USED ALONE IN CONTROLLING CODLING MOTH ON BLACK BEN DAVIS APPLES, IN THE EXPERIMENTS AT NEOGA, 1914

Plat	Treatment	Applications	Picked apples				
			Total No.	Percentage No. 1	Percentage affected by codling moth		
					Calyx	Side	Total
7	2–100 Corona dry arsenate of lead..............	1, 2, 3, 4, 5, 6	710	80	0.4	4.3	4.7
Check	No treatment............	None	332	0	12.3	85.0	97.3
8	4–100 Corona dry arsenate of lead..............	1, 2, 3, 4, 5, 6	2072	76	0.1	2.0	2.1
9	2–100 Sherwin-Williams dry arsenate of lead...	1, 2, 3, 4, 5, 6	1916	89	0.5	5.9	6.4
10	4–100 Sherwin-Williams dry arsenate of lead...	1, 2, 3, 4, 5, 6	2641	80	0.3	5.2	5.5
11	4–100 Sherwin-Williams paste arsenate of lead..	1, 2, 3, 4, 5, 6	2387	84	0.2	4.4	4.6
12	4–100 Grasselli paste arsenate of lead..........	1, 2, 3, 4, 5, 6	1162	73	4.0	12.0	16.0
Check	No treatment............	None	231	0	17.0	67.0	84.0
13	2–100 Grasselli powdered arsenate of lead.......	2, 3, 4, 5, 6	2688	46	4.7	27.0	31.7
14	4–100 Thomsen triplumbic paste arsenate of lead..	1, 2, 3, 4, 5, 6	1704	81	0.5	6.3	6.8
15	4–100 Dow paste arsenate of lead..............	1, 2, 3, 4, 5, 6	1707	83	.0	3.6	3.6

powdered arsenate of lead proved difficult to keep in suspension. Corona and Sherwin-Williams dry arsenates of lead were of practically the same efficiency as the pastes. The use of 2 pounds of dry arsenate of lead in each 100 gallons of spray was almost as efficient as 4 pounds, indicating that, for practical purposes, the smaller amount is sufficiently effective.

The fruit from the plats sprayed with arsenate of lead and lime sulfur was picked and examined October 23; the results are presented in Table 7. As will be seen, there were no wide differences in the effectiveness of the different arsenates of lead in controlling codling moth. Altho not shown in the table, it should be stated that none of the sprays caused injuries of any kind to the fruit.

TABLE 7.—EFFECTS OF VARIOUS BRANDS OF ARSENATE OF LEAD USED IN COMBINATION WITH LIME SULFUR IN CONTROLLING CODLING MOTH ON BLACK BEN DAVIS APPLES, IN THE EXPERIMENTS AT NEOGA, 1914

Plat	Treatment	Applications	Picked apples			
			Total No.	Percentage affected by codling moth		
				Calyx	Side	Total
16	4–100 Dow paste arsenate of lead with lime sulfur	1, 2, 3, 5				
	2–100 Corona dry arsenate of lead with lime	4, 6	1292	2.5	8.6	11.1
17	4–100 Sherwin-Williams paste arsenate of lead with lime sulfur	1, 2, 3, 5				
	2–100 Corona dry arsenate of lead with lime	4, 6	1841	2.4	9.2	11.6
Check	No treatment	None	456	6.0	51.0	57.0
18	2–100 Sherwin-Williams dry arsenate of lead with lime sulfur	1, 2, 3, 5				
	2–100 Corona dry arsenate of lead with lime	4, 6	1412	2.5	5.0	7.5
19	2–100 Grasselli powdered arsenate of lead with lime sulfur	2, 3, 5				
	2–100 Corona dry arsenate of lead with lime	4, 6	1440	2.0	7.0	9.0
20	4–100 Thomsen triplumbic paste arsenate of lead with lime sulfur	1, 2, 3, 5				
	2–100 Corona dry arsenate of lead with lime	4, 6	876	1.0	7.0	8.0
21	2–100 Corona dry arsenate of lead with lime sulfur	1, 2, 3, 5				
	2–100 Corona dry arsenate of lead with lime	4, 6	902	1.2	8.0	9.2

A comparison of Table 6 with Table 7 shows that a better control of codling moth was exercised by arsenate of lead alone than by arsenate of lead with lime sulfur. The difference, tho small, was consistent enough to indicate that the lime sulfur lessened the poisoning efficiency of the arsenate of lead or else proved attractive in some way to codling moth. The latter possibility would confirm observations recorded in Bulletin 185 (page 203).

FUNGICIDAL EFFICIENCY OF SOLUBLE SULFUR, ATOMIC SULFUR, CALCIUM HYPOSULFITE, COPPER FERROCYANIDE, AND TUBER TONIC

Niagara and Grasselli soluble sulfur, Thomsen atomic sulfur, calcium hyposulfite, copper ferrocyanide, and Sherwin-Williams tuber tonic were compared on plats consisting of ten Jonathan and four Grimes trees each. Lack of fungous infection, however, prevented obtaining information relating to the fungicidal value of these sprays. Copper ferrocyanide appeared to be the most adhesive; the other sprays were about equal in this respect. The fruit sprayed with calcium hyposulfite was more highly colored than that in any of the other plats. Tuber tonic seriously burned every leaf and injured every blossom to which it was applied, entirely destroying the crop from that plat, showing conclusively that it is a worthless and dangerous spray for apples. Soluble sulfur, used alone, caused slight foliage injury. Atomic sulfur injured about 10 percent of the fruit, causing a burn similar to lime-sulfur injury.

EFFECT OF PRESSURE ON BORDEAUX RUSSET

The effects of applications of different pressures on Bordeaux russet were compared on plats each consisting of ten Jonathan and four Grimes trees. The results are not tabulated, but may be stated as follows: Bordeaux applied at pressures above 150 pounds did not cause very much russet. Apples sprayed at higher pressures, however, were not so well colored as those sprayed at 135 pounds. Grimes apples sprayed at pressures of 175 pounds and higher were covered with minute russeted specks, hardly noticeable enough, however, to lessen their selling value.

EFFECTIVENESS OF CERTAIN STANDARD NOZZLES

Each plat in this group consisted of five Black Ben Davis trees. The sprays were applied with the nozzles named in Table 8.

EFFECT ON FOLIAGE

No differences in the appearance of the foliage in the various plats could be detected. More material was required when spraying with Bordeaux nozzles than with other nozzles, as much of it was lost on the ground.

EFFECT ON FRUIT

The fruit was picked and examined October 26, giving the results presented in Table 8. There were no appreciable differences in the effectiveness of the different nozzles in their degree of control of codling moth. The drenching spray of the Bordeaux nozzle saved no more fruit from second-brood codling moth than the misty, fog-like sprays from the other nozzles. In controlling the first brood, however, this nozzle was the most efficient. Owing to the absence of fungous diseases, there was no opportunity to compare the efficiency of the different nozzles in controlling them.

TABLE 8.—EFFECTS OF USING DIFFERENT KINDS OF NOZZLES IN APPLYING STANDARD SPRAY MIXTURES TO BLACK BEN DAVIS APPLES, IN THE EXPERIMENTS AT NEOGA, 1914

Plat	Nozzle used	Picked apples			
		Total No.	Percentage affected by codling moth		
			Calyx	Side	Total
28	Bordeaux	2100	.2	16.2	16.4
29	Morrill and Morley Eclipse	732	3.2	12.6	15.8
30	One Friend and one Gould Mistry	1335	5.0	13.8	18.8
Check	No treatment	282	14.7	76.0	90.7

EFFECTS OF SPECIAL SPRAYS APPLIED TO CONTROL DELAYED BROODS OF CODLING MOTH

In 1914 most of the first-brood codling moth appeared about the middle of June, a month later than usual. Late in August and on into September an apparently delayed second brood, the offspring of the delayed first brood, appeared. As no provision had been made in the regular spray schedule for applications to control codling moth appearing at these times, it was necessary to resort to extra sprays applied as soon as a diagnosis of this unusual condition could be made. These extra sprays were applied June 14 and September 1. To learn their effectiveness, the first one was omitted from one plat, the last one from another, and both from a third. Each plat consisted of five Black Ben Davis trees. The effects of the extra sprays are shown in Table 9.

These results show that the two extra sprays saved slightly more than half the total crop, reducing the injury from 56 percent in Plat J, which received only the regular applications, to 4.7 percent in Plat G, which received both extra applications in addition to the regular sprays. One extra application was helpful, but insufficient to give a satisfactory control of codling moth.

The excellent results obtained in this experiment, carried on in a season when codling moth was at its worst, show conclusively that it is possible to keep such close track of the development of the insect as to spray at such times as to hold it effectively in check.

TABLE 9.—EFFECTS OF SPECIAL APPLICATIONS OF ARSENATE OF LEAD APPLIED TO CONTROL DELAYED BROODS OF CODLING MOTH, IN THE EXPERIMENTS AT NEOGA, 1914

Plat	Treatment	Applications	Picked apples				
			Total No.	Percentage No. 1	Percentage affected by codling moth		
					Calyx	Side	Total
G	Four regular sprays..........	1, 2, 3, 5					
	Extra applications in June and September..............	4, 6	710	80	0.4	4.3	4.7
H	Four regular sprays..........	1, 2, 3, 5					
	Extra application in September only...............	6	496	51	8.3	29.0	37.3
I	Four regular sprays..........	1, 2, 3, 5					
	Extra application in June only	4	1360	48	11.0	23.0	34.0
J	Four regular sprays...........	1, 2, 3, 5					
	No extra applications.........		366	22	4.9	51.1	56.0
Check	No treatment...............	None	456	0	6.0	51.0	57.0

NOTE.—For all applications 2-100 Corona dry arsenate of lead with lime was used.

EFFECTS OF BANDING THE TREES AS A SUPPLEMENTARY MEANS OF CONTROLLING CODLING MOTH

When it became evident in June that a strenuous fight would have to be made to control codling moth, it was decided to place trap bands of paper or burlap on the trees in order to catch as many larvæ and pupæ as possible. The rough bark was first scraped from the tree trunks, when it is estimated that more than 6,000 larvæ were killed. Two bands were then placed on each tree, one six inches above the ground and the other just below the crotch. These were examined every seven days thruout the summer. The banding resulted in the trapping and subsequent destruction of more than 14,000 larvæ. In the bands on one of the unsprayed trees, 154 larvæ were found at one examination. It is believed, therefore, that banding is a useful supplement to spraying in controlling codling moth.

SUMMARY OF RESULTS AT NEOGA, 1914

1. Arsenate of lead, properly applied, controlled codling moth in spite of the severe 1914 infestation.

2. Arsenate of lead received from the Grasselli Chemical Company was less efficient in the control of codling moth than Corona dry,

Sherwin-Williams paste and dry, Thomsen triplumbic paste, and Dow paste arsenates of lead.

3. Corona dry and Sherwin-Williams dry arsenates of lead were equivalent in efficiency to the pastes.

4. Two pounds of Corona dry and two pounds of Sherwin-Williams dry arsenate of lead were practically as efficient as four pounds of the same material, as well as four pounds of any of the standard paste arsenates of lead.

5. All the arsenates of lead were less effective when used with lime sulfur than when used alone.

6. Copper ferrocyanide proved to be very adhesive.

7. Fruit sprayed with calcium hyposulfite was very highly colored.

8. Sherwin-Williams tuber tonic caused severe injury to the foliage and fruit.

9. Niagara soluble sulfur and Grasselli soluble sulfur caused a small amount of foliage injury.

10. Thomsen atomic sulfur burned about 10 percent of the fruit.

11. Drenching trees by the use of the Bordeaux nozzle did not prove any more efficient than spraying thru nozzles producing a mist in controlling second-brood codling moth, but was more efficient in controlling the first brood.

12. Owing to the irregularity with which codling moth appeared, over half the fruit from trees which were not given special applications for the delayed broods was infested.

13. Thirty-seven percent of the fruit from trees given one special application in September was injured by codling moth; 34-percent infestation resulted when one special application was given in June; while in properly sprayed fruit, receiving four regular applications and two special applications, the injury amounted to only 5 percent.

14. Banding trees with paper or burlap bands was found a satisfactory means of trapping the larvæ of the codling moth, thus affording an opportunity to kill them before they had transformed into moths.

SPRAYING EXPERIMENTS IN 1913 AT FLORA, CLAY COUNTY

BY W. A. RUTH, ASSOCIATE IN HORTICULTURAL CHEMISTRY

OBJECTS

The principal object of this experiment was to determine the effect of varying the amount of Bordeaux applied, the pressure at which the spray was applied, and the size of the nozzle openings, on the production of Bordeaux russet. A secondary object was to determine the effect of varying these factors on the control of insects and fungi.

BORDEAUX RUSSET: DESCRIPTION AND CAUSE

Aside from producing foliage injury, Bordeaux will bring about severe russeting of the fruit if applied to certain varieties of apples under certain conditions. Some varieties are more subject to russeting than others; the varieties Ben Davis and Jonathan, upon which this experiment was carried out, may be classed among the more susceptible. The russeting is due to the production of corky material which replaces the surface injured by the spray. This corky surface is usually light brown, but may be dark brown or black if the russeted areas are very small. The injury may be confined to scattered dots; if more severe, there may be irregular russeted streaks as well as dots; and if very severe, all or a large part of the surface of the fruit may be russeted.

The injury, according to Hedrick,[1] follows applications of Bordeaux made early in the season; later in the season, according to this investigator, after the hairs have been shed and the stomata changed into lenticels, immunity is probably acquired. At Flora, in experiments conducted by the writer in 1912 with Ben Davis and Jonathan trees, the application of Bordeaux made in April, just before the bloom, and the two following the bloom, made in May, all caused serious damage.[2] The application of this material made about July 1, however, when the apples were acquiring a waxy surface, caused no severe russet; a slight dotting was produced at this time, but it became inconspicuous by the time the fruit was ready to be picked. Experiments conducted with Ben Davis trees by Mr. A. J. Gunderson[2] at Griggsville showed that any one of the early applications of Bordeaux may result in the culling of a large part of the crop.

When Bordeaux was first used there was little complaint of injury. The apparatus with which the material was applied at that time was very crude compared with the machinery now employed. On account of the much greater pressures used since power sprayers have reached their present state of perfection, the increase in russeting has often been attributed to these greater pressures. A further basis for the assumption that pressure is a most important factor in the formation of russet is the difference in the severity of the russeting often to be observed in commercial orchards sprayed at high and at low pressures. In support of this idea a mechanical explanation was apparently at hand. According to this explanation the damage follows punctures made by gritty particles in the Bordeaux, and the number of the punctures and the severity of the resultant injury increase with the pressure.

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[1] U. P. Hedrick, New York (Geneva) Agr. Exp. Sta. Bul. 287, p. 163.

[2] J. C. Blair et al., Ill. Agr. Exp. Sta. Bul. 185.

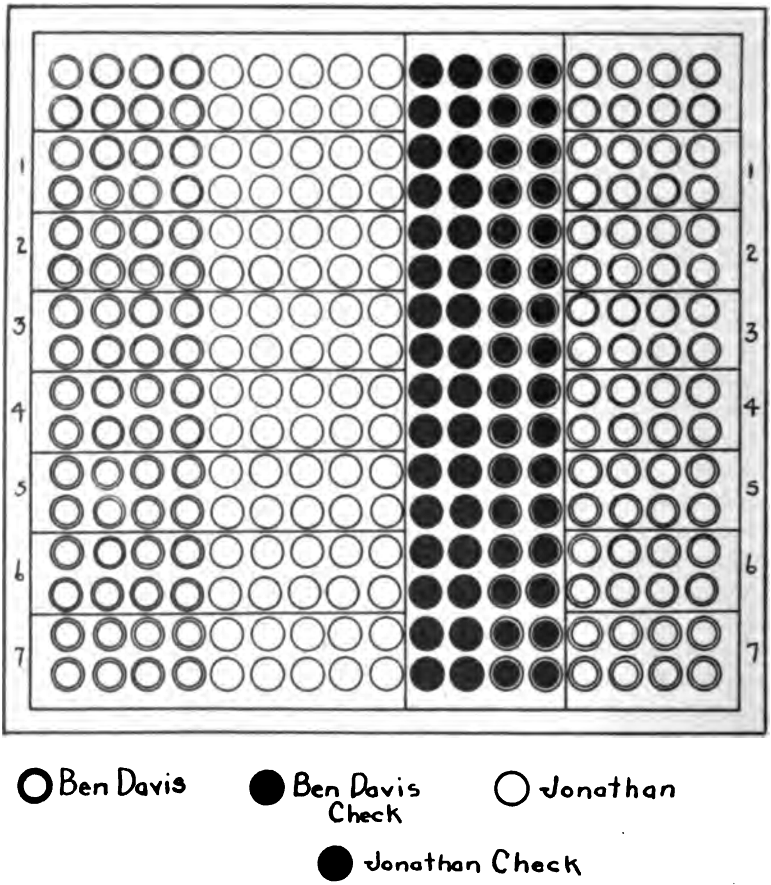

FIG. 4.—PLAN OF PLATS IN ORCHARD OF MRS. JOHN EGGINTON, FLORA, 1913
NOTE.—The neglected orchard was located immediately to the right.

It can hardly be assumed that a difference in the pressure is the only difference between the methods now used for applying the spray and those used formerly, or between high and low pressure spraying. More thoro spraying is probably done with power sprayers than was done before they came into use, and larger amounts of spray material per tree are no doubt being applied. Moreover, larger amounts are usually applied at high pressures than at low pressures. The pressure indicated at the pump cannot be assumed to be an accurate indicator of the striking force of the particles; the type of nozzle and the size of the nozzle openings affect the size of the drops of spray, and, in all probability, their striking force to at least as great an extent as their size. Even with nozzle openings of a uniform size, a high pressure breaks the spray into finer particles than does a low pressure.[1] It may therefore be imagined that the possible striking and injuring force may be actually greater if low pressures are used than would result from the use of high pressures, especially if large nozzle openings are used with the low pressures, and small nozzle openings with the high.

LOCATION AND DESCRIPTION OF ORCHARD

The orchard used in this experiment was the property of Mrs. John Egginton, and was located four and one-half miles west of Flora. The trees, which were well cared for, were seventeen years old the season of the experiment. A gradual, even slope, and a draw adjoining the lower end, provided good air drainage, especially for the upper third of the orchard, across which the plats were run. A neglected orchard immediately adjoined this part of the orchard. The arrangement of the plats is shown in Fig. 4.

TREATMENT

In order to restrict the number of plats, but one high and one low pressure were tested, one size of large nozzle opening and one size of small, and, as far as possible, a uniform large and a uniform small amount of spray. To obtain all the possible combinations of the three factors the experiment would have included eight treatments. The possible combinations and the methods used are shown in Table 10. Bordeaux arsenate of lead was used for the first and fourth applications, and lime sulfur arsenate of lead for the two intermediate applications.

When small amounts of spray were applied, the foliage was covered lightly but thoroly. With large amounts, the foliage was drenched. There was more or less unavoidable variation in the amounts applied to the plats in each class. The spray was applied from the upper side, most of the spray which reached the under sides of the leaves being that carried thru the tree at the high pressure. The high pressure was between 225 and 250 pounds, the low pressure, between 125 and 150 pounds. The large nozzle openings had twice the area of the small nozzle openings.

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[1] J. W. Lloyd, Ill. Agr. Exp. Sta. Bul. 114, p. 385.

TABLE 10.—TREATMENTS IN THE EXPERIMENTS AT FLORA, 1913

Plat	Pressure	Amount of spray	Size of nozzle openings
1	High	Large	Large
2	Low	Large	Large
3	Low	Small	Large
–[1]	High	Small	Large
4	High	Small	Small
5	Low	Small	Small
6	High	Large	Small
7	Low	Large	Small

[1] Because of the difficulty involved in distributing a small amount of spray evenly at a high pressure with large nozzle openings, this combination of factors was not tested.

The material was applied in the following manner: Each plat was completely sprayed at one time, with material made up and carried in one load. Each plat was sprayed from one side, thru the middle, and then from the other side, so that the trees of both varieties were finished practically at the same time, and that any possible differences in the method of spraying, which in any case would be slight, would be equalized as far as possible between the varieties.

The first, second, and third applications, which are, taken together, responsible for the control of scab, leaf spot (*Sphæropsis malorum* Pk.), first-brood codling moth, and the apple-leaf roller (*Archips rosaceana* Harris), were applied at favorable times. The third application is also partly responsible for the control of blotch. The apple flea-weevil (*Orchestes canus* Horn) confines its feeding to the earlier part of the season, and would be controlled by the early sprays if it is to be controlled according to the present schedule. The fourth application, which is designed to be partly responsible for the control of blotch (*Phyllosticta solitaria* E. & E.), directly responsible for the control of second-brood codling moth, and indirectly responsible for the control of the third brood, was applied too late to be of any great benefit.

APPARATUS AND MATERIALS

The sprays were prepared according to the methods described on pages 430 and 431. The Illinois formula was used in making the lime sulfur. Grasselli paste arsenate of lead, at the rate of 4 pounds to 100 gallons of spray, was always added to the fungicide.

In applying the sprays, Bean whirlpool nozzles were used. The discs of these nozzles, which are interchangeable, are regularly furnished with holes approximately .07 or .05 inch in diameter, and these sizes were used as the "large" and the "small" nozzle openings. The whirlpool type of nozzle is made by several firms, and is in common use in commercial orchards. Two power sprayers were used, one for the high-pressure sprays, the other for those applied at the low pressure. Both outfits were equipped with good propeller agitators.

WEATHER CONDITIONS

The weather during April, May, and the first part of June was very cool, and there was enough moisture to allow an attack of scab and blotch. The remainder of the season was unusually hot and dry. Conditions were favorable for the multiplication of codling moth.

SPRAY DATES

Four summer applications were made upon the following dates: April 17 to 19, May 7 to 8, May 28 to 31, and August 8 to 10. The fourth application was made after the danger of Bordeaux russeting was past.

EFFECT OF THE SPRAYS ON FOLIAGE

Leaf spot was thoroly controlled on all the sprayed trees, but caused a heavy loss of foliage on the unsprayed Ben Davis trees. A severe scab infection was present on the Ben Davis fruit, altho the foliage of the check trees of both varieties was almost free from this injury.

By the middle of June the foliage of both the sprayed and the unsprayed trees was thoroly riddled by apple flea-weevil. The first overwintering adults were observed April 3; the adults of the new generation were present on the foliage in the greatest numbers during the latter part of May and the first two weeks in June.

At the ends of the plats immediately adjoining the neglected orchard, apple-leaf rollers severely damaged the foliage of two or three rows of trees. On the trees farther away, the sprays controlled these insects to a large extent.

EFFECT OF THE SPRAYS ON FRUIT

The effects of varying each one of the three factors, pressure, amount, and size of nozzle opening, as tested on each of the two varieties, are presented in Tables 11 to 16. In each table three plats are compared with three other plats; each of the three plats shown on one side of the table was treated similarly to the opposite one of the other three, except for one varying factor common to the entire group of six. In the first two tables the pressure at which the spray was applied is the common varying factor; in the next two it is the amount of spray; and in the last two it is the size of the nozzle openings.

On account of the large number of codling moths and the small and scattered crop of fruit, the degree of control of these insects cannot be attributed entirely to the relative efficiency of the various treatments. It is well known that, with a small crop and an abundance of moths, control is especially difficult. When the set of fruit varies among various plats, following a scattered bloom, as it did in this experiment, especially on the Ben Davis trees, differences in control must be due to some extent to differences in the set. For this reason, codling-moth data of Ben Davis fruit are omitted in the following tables. The data for the control of these insects entering the calyxes of the Jonathans, however, seem to be fairly consistent, and are therefore presented. All the picked Jonathans were examined for the various injuries recorded, but only the Ben Davis apples from the end of the plats farthest from the neglected orchard.

TABLE 11.—EFFECT OF SPRAYING BEN DAVIS APPLES WITH DIFFERENT PRESSURES, IN THE EXPERIMENTS AT FLORA, 1913[1]

Amount of spray	Size of nozzle openings	High pressure				Low pressure			
		Plat	Percentage of picked apples affected by—			Plat	Percentage of picked apples affected by—		
			Scab	Blotch	Severe russet		Scab	Blotch	Severe russet
Large	Large	1	.0	6.2	30.6	2	.0	3.7	33.4
Small	Small	4	5.5	29.4	13.9	5	8.8	32.3	8.3
Large	Small	6	.5	13.3	23.8	7	4.6	13.6	25.3
		Average	2.0	16.3	22.8	Average	4.5	16.5	22.3
No treatment......		Check	62.2	56.6	2.1	Check	62.2	56.6	2.1

TABLE 12.—EFFECT OF SPRAYING JONATHAN APPLES WITH DIFFERENT PRESSURES, IN THE EXPERIMENTS AT FLORA, 1913[1]

Amt. of spray	Size of nozzle openings	High pressure					Low pressure				
		Plat	Percentage of picked apples affected by—				Plat	Percentage of picked apples affected by—			
			Scab	Blotch	Codling moth (calyx)	Severe russet		Scab	Blotch	Codling moth (calyx)	Severe russet
Large	Large	1	.9	6.1	6.3	5.7	2	.2	5.4	4.8	17.9
Small	Small	4	2.0	19.5	13.8	7.7	5	2.5	18.9	23.2	18.4
Large	Small	6	.6	5.5	4.0	36.9	7	1.0	11.2	11.4	37.5
		Average	1.2	10.4	8.0	16.8	Average	1.2	11.8	13.1	24.6
No treatment		Check	34.9	52.6	50.1	2.9	Check	34.9	52.6	50.1	2.9

[1] Each plat was sprayed four times; Bordeaux arsenate of lead was used for the first and fourth applications, and lime sulfur arsenate of lead for the two intermediate applications.

EFFECT OF VARYING THE PRESSURE

On the Ben Davis apples, the amount of russet produced by the spray was practically equal at both pressures. On the Jonathan apples, more russet was produced, in every case, at low than at high pressure. On both varieties, blotch and scab were controlled, on the average, with almost equal thoroness at both pressures. The control of codling moths entering the calyxes of the Jonathans was better, on the average, where the spray was applied at high pressure.

EFFECT OF VARYING THE AMOUNT OF SPRAY

In every case where comparisons could be made, the use of a large amount of spray resulted in decidedly more russet than the use of a small amount. The control of scab and blotch on both varieties, and of codling moths entering the calyxes of the Jonathans, was better, and with one exception much better, where large amounts of spray were used.

TABLE 13.—EFFECT OF SPRAYING BEN DAVIS APPLES WITH DIFFERENT AMOUNTS, IN THE EXPERIMENTS AT FLORA, 1913[1]

Pressure	Size of nozzle openings	Large amount				Small amount			
		Plat	Percentage of picked apples affected by—			Plat	Percentage of picked apples affected by—		
			Scab	Blotch	Severe russet		Scab	Blotch	Severe russet
Low	Large	2	.0	3.7	33.4	3	4.4	32.8	15.8
High	Small	6	.5	13.3	23.8	4	5.5	29.4	13.9
Low	Small	7	4.6	13.6	25.3	5	8.8	32.3	8.3
		Average	1.7	10.2	27.5	Average	6.2	31.5	12.7
No treatment		Check	62.2	56.6	2.1	Check	62.2	56.6	2.1

TABLE 14.—EFFECT OF SPRAYING JONATHAN APPLES WITH DIFFERENT AMOUNTS, IN THE EXPERIMENTS AT FLORA, 1913[1]

Pressure	Size of nozzle openings	Large amount					Small amount				
		Plat	Percentage of picked apples affected by—				Plat	Percentage of picked apples affected by—			
			Scab	Blotch	Codling moth (calyx)	Severe russet		Scab	Blotch	Codling moth (calyx)	Severe russet
Low	Large	2	.2	5.4	4.8	17.9	3	1.5	14.4	7.9	9.0
High	Small	6	.6	5.5	4.0	36.9	4	2.0	19.5	13.8	7.7
Low	Small	7	1.0	11.2	11.4	37.5	5	2.5	18.9	23.2	18.4
		Average	.6	7.4	6.7	30.8	Average	2.0	17.6	15.0	11.7
No treatment		Check	34.9	52.6	50.1	2.9	Check	34.9	52.6	50.1	2.9

[1] Each plat was sprayed four times; Bordeaux arsenate of lead was used for the first and fourth applications, and lime sulfur arsenate of lead for the two intermediate applications.

EFFECT OF VARYING THE SIZE OF THE NOZZLE OPENINGS

In every case more russet was produced on the Ben Davis apples sprayed with large nozzle openings than on those sprayed with small nozzle openings, while the opposite result was produced in every case on the Jonathans. On the average, three times as much russet appeared on Jonathan apples sprayed with large nozzle openings as on those sprayed with small nozzle openings. The difference may be due to a greater susceptibility of the Jonathan tissue to a small amount of Bordeaux, in comparison to its susceptibility to a large amount, and to a better distribution of the spray. The better distribution, which would follow the use of small nozzle openings and the production of a finer mist, might result in the production of a greater number of smaller covered areas. The use of low pressures, in comparison with high pressures, modifies the distribution in the same way, and, as has been stated in the discussion of the effect of varying the pressure, produces the same result.

TABLE 15.—EFFECT OF SPRAYING BEN DAVIS APPLES WITH DIFFERENT-SIZED NOZZLE OPENINGS, IN THE EXPERIMENTS AT FLORA, 1913[1]

Pressure	Amount of spray	Large nozzle openings				Small nozzle openings			
		Plat	Percentage of picked apples affected by—			Plat	Percentage of picked apples affected by—		
			Scab	Blotch	Severe russet		Scab	Blotch	Severe russet
High	Large	1	.0	6.2	30.6	6	.5	13.3	23.8
Low	Large	2	.0	3.7	33.4	7	4.6	13.6	25.3
Low	Small	3	4.4	32.8	15.8	5	8.8	32.3	8.3
		Average	1.5	14.2	26.6	Average	4.6	19.7	19.1
No treatment.....		Check	62.2	56.6	2.1	Check	62.2	56.6	2.1

TABLE 16.—EFFECT OF SPRAYING JONATHAN APPLES WITH DIFFERENT-SIZED NOZZLE OPENINGS, IN THE EXPERIMENTS AT FLORA, 1913[1]

Pressure	Amt. of spray	Large nozzle openings					Small nozzle openings				
		Plat	Percentage of picked apples affected by—				Plat	Percentage of picked apples affected by—			
			Scab	Blotch	Codling moth (calyx)	Severe russet		Scab	Blotch	Codling moth (calyx)	Severe russet
High	Large	1	.9	6.1	6.3	5.7	6	.6	5.5	4.0	36.9
Low	Large	2	.2	5.4	4.8	17.9	7	1.0	11.2	11.4	37.5
Low	Small	3	1.5	14.4	7.9	9.0	5	2.5	18.9	23.2	18.4
		Average	.9	8.6	6.3	10.9	Average	1.4	11.9	12.9	30.9
No treatment.		Check	34.9	52.6	50.1	2.9	Check	34.9	52.6	50.1	2.9

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[1] Each plat was sprayed four times; Bordeaux arsenate of lead was used for the first and fourth applications, and lime sulfur arsenate of lead for the two intermediate applications.

The control of scab and blotch was better on Ben Davis apples when large nozzle openings were used. The same was true for blotch and codling-moth calyx injury on the Jonathans. Scab on the Jonathans was controlled almost equally well when large and small nozzle openings were used.

SUMMARY OF RESULTS AT FLORA, 1913

1. The amount of spray applied was the most important factor in the production of russet; large amounts increased this injury, but were more effective in protecting the fruit from scab, blotch, and codling moth entering the calyxes, than were small amounts.
2. It was conclusively shown that applying the spray at high pressure did not increase the amount of Bordeaux russet. The pressure employed had no effect on the control of scab or blotch, but the value of high pressures in the control of codling-moth calyx injury was indicated.
3. On the Ben Davis apples, a greater amount of russet was produced where large nozzle openings were used than where small nozzle openings were used; on the Jonathan apples, the use of small nozzle openings gave the greater amount of russet. Large nozzle openings gave a better control, in general, of scab, blotch, and codling-moth calyx injury.
4. Spraying was of no value in controlling the apple flea-weevil.
5. The foliage of all the sprayed plats was well protected from leaf spot.
6. The foliage of all the sprayed plats was well protected from the apple-leaf roller except on the trees adjoining the neglected orchard.

SPRAYING EXPERIMENTS IN 1913 AT GRIGGSVILLE, PIKE COUNTY

BY ALFRED J. GUNDERSON, FIRST ASSISTANT IN POMOLOGY

OBJECTS

In the spraying work at Griggsville during 1913, experiments were conducted with a view to studying the following points in summer spraying: (1) the relative values of lime sulfur and Bordeaux; (2) the effects of using Bordeaux for some applications and lime sulfur for other applications in the same season's operations; (3) the relative values of paste and powdered arsenates of lead; (4) the relative values of various strengths of lime sulfur; (5) the fungicidal and insecticidal values of copper ferrocyanide made in different ways; (6) the relative values of proprietary lime-sulfur compounds; (7) the relative values of light and heavy applications of lime sulfur arsenate of lead and Bordeaux arsenate of lead.

LOCATION AND DESCRIPTION OF ORCHARD

The orchard used for these experiments belonged to Mr. C. G. Winn, and was located one and one-half miles south of Griggsville. A block of 179 fifteen-year-old Ben Davis trees, planted thirty-two feet apart each way, was chosen for the work.

In laying out the experiments, the trees were divided into twenty-eight plats of four to six trees each, and two unsprayed or check rows were left thru the entire length of the orchard. The plats which were to be compared were grouped, and those of each group were sprayed as nearly as possible under the same conditions. The arrangement of the plats is shown in Fig. 5.

APPARATUS AND MATERIALS

The standard sprays were prepared as described on pages 430 and 431. Applications were made with a Gould hand spray outfit at 115 to 125 pounds pressure. Friend disc nozzles were used.

WEATHER CONDITIONS

The weather during April, May, and the first part of June was cool, with very little rain. The remainder of the season was unusually hot and dry.

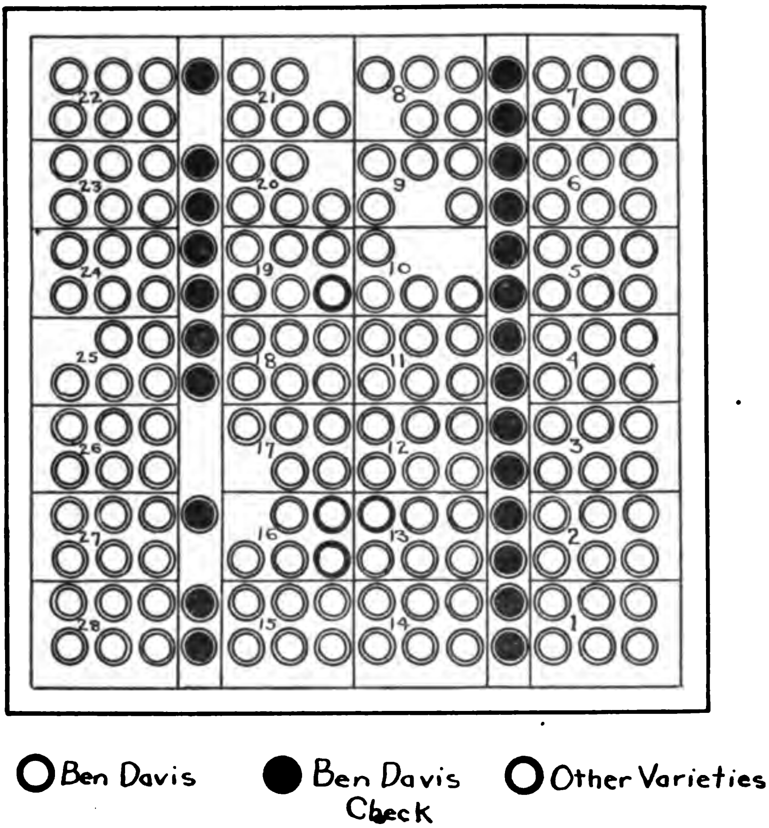

FIG. 5.—PLAN OF PLATS IN ORCHARD OF C. G. WINN, GRIGGSVILLE, 1913

SPRAY DATES

Three summer applications were made upon the following dates: April 21 to 23, May 6 to 9, and May 20 to 23.

RELATIVE VALUES OF LIME SULFUR AND BORDEAUX

Experiments at Griggsville during 1912 showed lime sulfur and Bordeaux to be equally effective in the control of scab.[1] The apples sprayed with lime sulfur had higher color and finish and the foliage was more vigorous than where Bordeaux was used. The comparison of these two sprays was continued in 1913, however, to gain further information regarding the relative values of the two sprays. Two plats were treated as shown in Table 17.

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[1] J. C. Blair et al., Ill. Agr. Exp. Sta. Bul. 185, p. 176.

EFFECT ON FOLIAGE

The foliage of the unsprayed plat as well as that of both sprayed plats was free from scab during the entire season. The foliage of the plat sprayed with lime sulfur was more vigorous than that sprayed with Bordeaux. The former plat was practically free from spray injury, while on the latter plat considerable spray injury appeared late in September in the form of brown spots. Both plats showed a slight amount of leaf spot (*Sphæropsis malorum*), but a comparison with the infection present on the unsprayed trees shows that the sprays were reasonably effective in controlling this disease.

EFFECT ON FRUIT

The apples from these plats were picked and examined September 30. The results are given in Table 17. The comparative fungicidal values of lime sulfur and Bordeaux were less conclusively shown than had been hoped for, because fungous diseases were present in only small amounts. Both sprays gave perfect control of scab and sooty blotch.

Plat 1, sprayed with Bordeaux, showed even more damage from codling moth than the unsprayed plat and four times more than Plat 2, sprayed with lime sulfur. It is believed, however, that this was due to uneven infestation rather than to the effects of the treatment. Curculio injury was reduced from 67.83 percent on the unsprayed plat to 21.94 percent on Plat 1, and to 10.3 percent on Plat 2.

The most important difference between the effects of these sprays upon the fruit is shown in the amount of russet recorded. There was 64 percent serious and 26.5 percent slight russet on the fruit from trees sprayed with Bordeaux, as compared with .5 percent serious and 3.05 percent slight russet on the fruit from trees sprayed with lime sulfur. However, the amount of russet recorded for the unsprayed trees was .66 percent serious and 2.5 percent slight; hence it may be concluded that lime sulfur was not responsible for the russet on the trees sprayed with that material, and that 63.34 percent serious and 24 percent slight russet, in Plat 1, can be attributed to Bordeaux injury.

The grade percentages show that the plat sprayed with lime sulfur produced 48 percent No. 1's, 23 percent No. 2's, and 29 percent culls, as compared with 9 percent, 15 percent, and 76 percent of the same grades, respectively, produced by the plat sprayed with Bordeaux. The latter plat had fewer No. 1's and more culls than the unsprayed plat. These differences were due to Bordeaux russet. The apples sprayed with lime sulfur had excellent color and finish at picking time, and were of good size. Those sprayed with Bordeaux, on the other hand, lacked color, and were very small, badly russeted, and distorted.

TABLE 17.—EFFECTS OF BORDEAUX AND LIME SULFUR IN COMBINATION WITH ARSENATE OF LEAD, IN THE EXPERIMENTS AT GRIGGSVILLE, 1913

Plat	Treatment	Applications	Percentage grades of picked apples			Percentage of picked apples affected by—								
						Scab		Sooty blotch		Codling moth		Curculio	Russet	
			No. 1	No. 2	Culls	Serious	Slight	Serious	Slight	Calyx	Side	Serious	Serious	Slight
1	Bordeaux arsenate of lead. . .	1,2,3	9	15	76	.00	.00	.00	.00	2.71	31.08	21.94	64.00	26.50
2	Lime sulfur arsenate of lead.	1,2,3	48	23	29	.00	.00	.00	.00	.00	7.25	10.30	.50	3.05
CheckA	No treatment.	None	21	16	63	.58	1.75	6.66	16.08	2.50	12.75	67.83	.66	2.50

TABLE 18.—EFFECTS OF USING BORDEAUX FOR SOME APPLICATIONS AND LIME SULFUR FOR OTHER APPLICATIONS IN THE SAME SEASON'S OPERATIONS, IN THE EXPERIMENTS AT GRIGGSVILLE, 1913

Plat	Treatment	Applications	Percentage grades of picked apples			Percentage of picked apples affected by—								
						Scab		Sooty blotch		Codling moth		Curculio	Russet	
			No. 1	No. 2	Culls	Serious	Slight	Serious	Slight	Calyx	Side	Serious	Serious	Slight
1	Bordeaux arsenate of lead. . .	1,2,3	9	15	76	.00	.00	.00	.00	2.71	31.08	21.94	64.00	26.50
2	Lime sulfur arsenate of lead. .	1,2,3	48	23	29	.00	.00	.00	.00	.00	7.25	10.30	.50	3.05
3	Bordeaux arsenate of lead. . .	1												
	Lime sulfur arsenate of lead. .	2,3	39	23	38	.00	.00	.00	1.04	.33	14.27	13.70	7.12	24.83
4	Lime sulfur arsenate of lead. .	1,2												
	Bordeaux arsenate of lead . .	3	22	26	52	.00	.00	.00	.00	.16	10.50	12.16	23.00	63.50
5	Bordeaux arsenate of lead. . .	1,3												
	Lime sulfur arsenate of lead. .	2	31	27	42	.00	.00	.00	.10	.70	12.70	10.30	30.00	44.90
Check A	No treatment	None	21	16	63	.58	1.75	6.66	16.08	2.50	12.75	67.83	.66	2.50

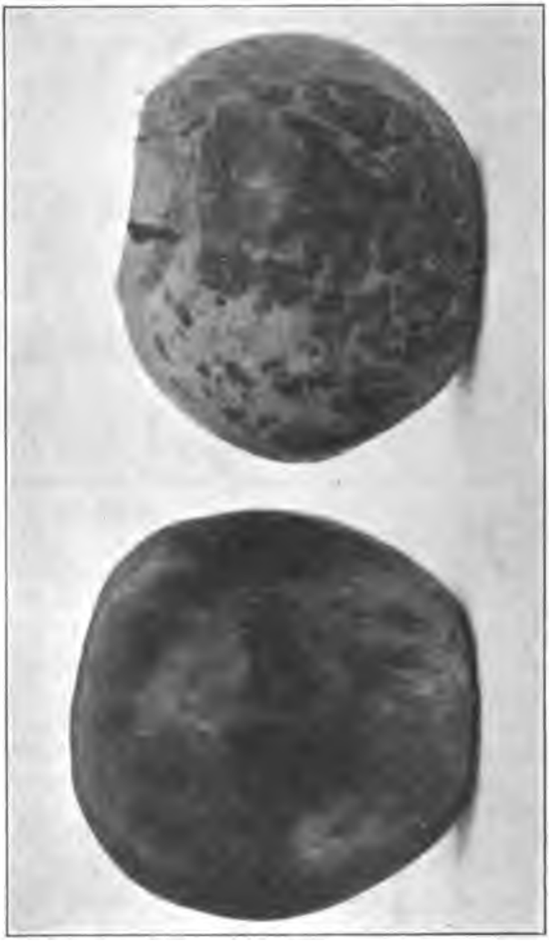

Fig. 6.—The Apple on the Left was from a Tree Sprayed with Lime Sulfur, That on the Right from a Tree Sprayed with Bordeaux

EFFECTS OF USING BORDEAUX FOR SOME APPLICATIONS AND LIME SULFUR FOR OTHER APPLICATIONS IN THE SAME SEASON'S OPERATIONS

The effect of using Bordeaux for some applications and lime sulfur for other applications in the same season's operations was made the subject of an experiment in which plats were treated as shown in Table 18.

EFFECT ON FOLIAGE

No scab appeared on the foliage of the sprayed plats during the entire season. A slight amount of spray injury appeared late in September, and also a light infection of frog-eye fungus (*Sphæropsis malorum*). In general, however, the foliage of these plats was vigorous and healthy.

EFFECT ON FRUIT

The apples from these plats were picked and examined September 30 and October 1. The results are given in Table 18. These results show that all the sprayed apples were free from scab and that sooty blotch was almost perfectly controlled. The brood of codling moth entering at the calyx was well controlled in Plats 2, 3, 4, and 5. The irregular and inconsistent results shown in the control of codling moth entering at the side, mostly larvæ of the late brood, indicate that three applications of spray made early in the season were ineffective in preventing damage by codling moth appearing late in the season. Curculio injury was greatly reduced by all the treatments.

Here again the most important differences are brought out in the russet columns. Since the unsprayed plat showed .66 percent serious and 2.5 percent slight russet, the true effects of the sprays are determined by subtracting the amounts of russet on the unsprayed trees from those on the sprayed trees. Thus we find that in Plat 3, Bordeaux applied at the cluster-bud stage actually caused 6.46 percent serious and 22.33 percent slight russet; that in Plat 4, Bordeaux applied two weeks after the fall of the bloom caused 22.34 percent serious and 61 percent slight russet; and that in Plat 5, Bordeaux applied both at the cluster-bud stage and two weeks after the fall of the bloom caused 29.34 percent serious and 42.4 percent slight russet. These results indicate, then, that Bordeaux, under the conditions of this experiment, when applied either just before the bloom or within two weeks after the fall of the bloom, will russet the fruit. Russet greatly reduced the color and smoothness of the apples on all plats sprayed with one or more applications of Bordeaux.

TABLE 19.—EFFECTS OF A POWDERED ARSENATE OF LEAD IN COMPARISON WITH A PASTE ARSENATE OF LEAD, IN THE EXPERIMENTS AT GRIGGSVILLE, 1913

Plat	Treatment	Applications	Percentage grades of picked apples			Percentage of picked apples affected by—								
						Scab		Sooty blotch		Codling moth		Curculio	Russet	
			No. 1	No. 2	Culls	Serious	Slight	Serious	Slight	Calyx	Side	Serious	Serious	Slight
6	Arsenate of lead (paste) alone	1, 2, 3	41	30	29	.00	.00	.00	1.25	.12	9.77	6.82	.00	1.00
7	Arsenate of lead (powdered) alone	1, 2, 3	56	23	21	.40	1.70	.30	.00	.24	9.11	9.01	.10	.90
8	Bordeaux arsenate of lead (powdered)	1, 2, 3	25	28	47	.00	.00	.00	.00	.20	10.80	14.00	49.60	38.80
9	Lime sulfur arsenate of lead (powdered)	1, 2, 3	52	23	25	.00	.00	.00	.00	.40	8.67	5.96	1.62	7.13
Check A	No treatment	None	21	16	63	.58	1.75	6.66	16.08	2.50	12.75	67.83	.66	2.50

NOTE.—Corona dry and Grasselli paste arsenates of lead were used.

TABLE 20.—EFFECTS OF VARIOUS STRENGTHS OF LIME SULFUR IN COMBINATION WITH ARSENATE OF LEAD, IN THE EXPERIMENTS AT GRIGGSVILLE, 1913

Plat	Treatment	Applications	Percentage grades of picked apples			Percentage of picked apples affected by—								
						Scab		Sooty blotch		Codling moth		Curculio	Russet	
			No. 1	No. 2	Culls	Serious	Slight	Serious	Slight	Calyx	Side	Serious	Serious	Slight
10	Lime sulfur (1 in 12) arsenate of lead	1, 2, 3	52	26	22	.00	.00	.00	.00	.00	4.87	4.73	1.16	7.61
11	Lime sulfur (1 in 14) arsenate of lead	1, 2, 3	49	23	28	.00	.00	.00	.00	.30	6.10	4.30	.70	6.80
12	Lime sulfur (1 in 18) arsenate of lead	1, 2, 3	53	24	23	.00	.00	.00	.00	.16	8.00	4.83	.33	1.16
13	Lime sulfur (1 in 24) arsenate of lead	1, 2, 3	37	45	18	.00	.00	.00	.00	.00	5.66	9.83	.50	1.50
14	Lime sulfur (1 in 36) arsenate of lead	1, 2, 3	49	18	33	.00	.00	.00	.00	.40	14.56	14.12	.20	1.46
15	Lime sulfur (1 in 72) arsenate of lead	1, 2, 3	44	17	39	.00	.00	.00	.00	.25	5.87	21.00	.12	.24
Check A	No treatment	None	21	16	63	.58	1.75	6.66	16.08	2.50	12.75	67.83	.66	2.50

RELATIVE VALUES OF PASTE AND POWDERED ARSENATES OF LEAD

The standard brands of arsenate of lead used in the spraying experiments previous to 1913 were in the paste form. Such powdered arsenates of lead as had appeared up to that time had not proved satisfactory. In 1913 a new powdered arsenate of lead, Corona dry, showed promising qualities in laboratory tests and was accordingly included in the schedule of treatments in the field tests. Plats were sprayed with powdered and paste forms, separately and in combination with Bordeaux and lime sulfur, as shown in Table 19.

EFFECT ON FOLIAGE

The foliage of Plats 6 and 7 was very good thruout the season. It was free from scab, and showed only a slight amount of tip and edge burning due to the spray. Plat 8, however, sprayed with Bordeaux arsenate of lead (powdered), showed considerable spray injury late in the season. The foliage of Plat 9, where lime sulfur arsenate of lead (powdered) was used, was excellent.

EFFECT ON FRUIT

The apples from these plats were picked and examined October 2 and 3. As will be seen in Table 19, all the sprayed plats were entirely free from scab except Plat 7, where an insignificant infection appeared. No scab or sooty blotch appeared in the plats where Bordeaux and lime sulfur were used with the arsenate of lead. Very slight infection of sooty blotch occurred in Plats 6 and 7, where the paste and powdered arsenates of lead, respectively, were used alone. From the amount of infection present in the check plat, it would appear that these sprays had exercised a beneficial fungicidal action.

The brood of codling moth entering at the calyx was effectively reduced by both the paste and the powdered arsenate of lead. Control of codling-moth side injury, however, was less effective. Both forms of arsenate of lead greatly reduced curculio injury, with no special advantage in favor of either.

The plat sprayed with powdered arsenate of lead produced a larger percentage of No. 1 apples than that sprayed with paste arsenate of lead, but the records of insect and fungous injuries indicate that other factors than the sprays were responsible for this result. Neither paste nor powdered arsenate of lead used alone appeared to cause spray russet; there was less on the apples sprayed with these materials than on the apples in the check plats. The color, finish, and size of the fruit in Plats 6 and 7 were excellent.

It is concluded from these experiments, therefore, that in every way the powdered form of arsenate of lead used (Corona) is as effective as the paste (Grasselli) with which it was compared.

TABLE 21.—EFFECTS OF DIFFERENT METHODS OF MAKING COPPER FERROCYANIDE ON ITS FUNGICIDAL VALUE, IN THE EXPERIMENTS AT GRIGGSVILLE, 1913

Plat	Treatment	Applications	Percentage grades of picked apples			Percentage of picked apples affected by—								
						Scab		Sooty blotch		Codling moth		Curculio	Russet	
			No. 1	No. 2	Culls	Serious	Slight	Serious	Slight	Calyx	Side	Serious	Serious	Slight
16	Copper ferrocyanide alone (2-2-100); mixed, concentrated, and hot......	1, 2, 3	19	15	66	.00	.00	.00	.00	6.87	22.57	55.08	.36	.50
19	Copper ferrocyanide arsenate of lead (2-2-4-100); mixed, concentrated, and hot...............	1, 2, 3	50	17	33	.00	.00	.00	3.45	.39	10.76	8.56	.33	1.66
17	Copper ferrocyanide alone (2-2-100); mixed, concentrated, and cold.....	1, 2, 3	22	14	64	.00	.16	.66	2.50	11.33	20.83	57.33	.00	.00
20	Copper ferrocyanide arsenate of lead (2-2-4-100); mixed, concentrated and cold..................	1, 2, 3	46	23	31	.00	.16	.16	.33	.16	8.33	13.00	.00	.00
18	Copper ferrocyanide alone (2-2-100); mixed, diluted, and cold......	1, 2, 3	26	13	61	.00	.66	.00	.16	7.66	20.66	62.00	.00	.83
21	Copper ferrocyanide arsenate of lead (2-2-4-100); mixed, diluted, and cold	1, 2, 3	47	24	29	.00	.00	.00	.10	.60	7.90	10.80	.10	.10
Check B	No treatment.............	None	20	15	65	.33	1.08	.50	4.50	3.66	12.75	57.33	.00	.41

RELATIVE VALUES OF VARIOUS STRENGTHS OF LIME SULFUR

In order to determine the efficiencies of various strengths of lime sulfur, plats were sprayed as shown in Table 20.

EFFECT ON FOLIAGE

The foliage of all the sprayed plats was free from scab during the entire season. There was, however, a slight infection of frogeye fungus. Plat 10 showed foliage injury to an extent indicating that one part of commercial concentrated lime sulfur in twelve of spray was too strong a solution. Aside from this, the foliage of all the plats was vigorous and of good color.

EFFECT ON FRUIT

The apples from these plats were picked and examined October 3 to 6. The results are given in Table 20. The fruit from the sprayed plats was entirely free from scab and sooty blotch. Codling moth entering at the calyx was well controlled, but the control of late-brood codling moth was inconsistent and unsatisfactory, owing to the fact that no late sprays were applied. Injury from curculio was greatly reduced by all the sprays. Plats 10 and 11 had a small percentage of russet; the remaining plats were practically free from it.

The fruit from these plats took on a high color and a waxy finish, and was of good size. Here again, as in the experiments at Griggsville in 1912, was illustrated the stimulating effect of lime sulfur arsenate of lead in improving the color and finish of the fruit.[1]

FUNGICIDAL AND INSECTICIDAL VALUES OF COPPER FERROCYANIDE MADE IN DIFFERENT WAYS

Copper ferrocyanide made according to the full and equal dilution method, with 2 pounds of copper sulfate and 2 pounds of potassium ferrocyanide in 100 gallons of spray, proved useless as a fungicide and insecticide in 1912, in the experiments at Griggsville. In 1913 it was decided to test this spray when prepared by other methods. Accordingly several plats were sprayed with copper ferrocyanide, alone and in combination with arsenate of lead, prepared as shown in Table 21.

EFFECT ON FOLIAGE

The foliage of all the sprayed plats was free from scab during the entire season. That of Plats 19, 20, and 21 was more vigorous and of a darker green than that of Plats 16, 17, and 18. This difference may have been due to an invigorating effect exercised by the arsenate of lead. All plats had a small amount of spray injury in the form of small, brown spots. Insect work on Plats 16, 17, and 18 was greater than on the other plats, where arsenate of lead was added to the sprays. A slight infection of frog-eye fungus was present on all these plats.

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[1] J. C. Blair et al., Ill. Agr. Exp. Sta. Bul. 185, p. 186.

EFFECT ON FRUIT

The apples from these plats were picked and examined October 6 and 7. The results are given in Table 21. The fungous infection of the unsprayed apples was so small that the differences favoring the various sprayed plats are not believed to be significant enough to warrant drawing conclusions on the effectiveness of copper-ferrocyanide sprays as fungicides. As insecticides they proved wholly worthless when used without arsenate of lead. The color of the fruit sprayed with copper ferrocyanide alone was decidedly less attractive than that of the fruit sprayed with copper ferrocyanide and arsenate of lead. The general results of the experiment are considered unfavorable to the use of copper ferrocyanide when made by any of the methods here used.

RELATIVE VALUES OF PROPRIETARY LIME-SULFUR COMPOUNDS

Thomsen atomic sulfur, Niagara soluble sulfur, and lime sulfur were tested and compared as shown by the treatments indicated in Table 22.

EFFECT ON FOLIAGE

The foliage of the sprayed plats was free from any infection of scab or other fungi during the entire season. Plats 22 and 24 had a very vigorous dark green foliage, free from spray injury. The foliage of Plat 23, however, sprayed with Niagara soluble sulfur, developed a severe tip and edge burning a few days after both the second and the third application, and as a consequence was scanty the rest of the season.

EFFECT ON FRUIT

The apples from these plats were picked and examined October 7, 8, and 9. The results are given in Table 22. The fruit from these plats was practically free from scab and sooty blotch. In comparing the sprayed plats with the check plat, it will be seen that the sprays materially reduced codling-moth and curculio injuries. Neither Thomsen atomic sulfur nor Niagara soluble sulfur caused any russeting of the fruit. The plat sprayed with lime sulfur showed 2 percent serious and 6.16 percent slight russet.

TABLE 22.—EFFECTS OF THOMSEN ATOMIC SULFUR, NIAGARA SOLUBLE SULFUR, AND GRASSELLI LIME SULFUR IN COMBINATION WITH ARSENATE OF LEAD, IN THE EXPERIMENTS AT GRIGGSVILLE, 1913

Plat	Treatment	Applications	Percentage grades of picked apples			Percentage of picked apples affected by—								
						Scab		Sooty blotch		Codling moth		Curculio	Russet	
			No. 1	No. 2	Culls	Serious	Slight	Serious	Slight	Calyx	Side	Serious	Serious	Slight
22	Thomsen atomic sulfur arsenate of lead (14-4-100)..	1, 2, 3	42	28	30	.00	.00	.0	.12	.12	6.75	6.75	0	.00
23	Niagara soluble sulfur arsenate of lead (4-4-100)...	1, 2, 3	56	22	22	.00	.00	.0	.10	.10	3.10	6.20	0	.20
24	Grasselli lime sulfur arsenate of lead (3-4-100).......	1, 2, 3	48	19	33	.00	.16	.0	.00	.66	6.50	12.66	2	6.16
Check B	No treatment............	None	20	15	65	.33	1.08	.5	4.50	3.66	12.75	57.33	0	.41

TABLE 23.—EFFECTS OF LIGHT AND HEAVY APPLICATIONS OF LIME SULFUR ARSENATE OF LEAD AND BORDEAUX ARSENATE OF LEAD IN THE EXPERIMENTS AT GRIGGSVILLE, 1913

Plat	Treatment	Applications	Percentage grades of picked apples			Percentage of picked apples affected by—								
						Scab		Sooty blotch		Codling moth		Curculio	Russet	
			No. 1	No. 2	Culls	Serious	Slight	Serious	Slight	Calyx	Side	Serious	Serious	Slight
25	Bordeaux arsenate of lead (light)...............	1, 2, 3	22	13	65	.00	.00	.0	.0	2.62	20.82	39.25	26.00	56.37
26	Bordeaux arsenate of lead (heavy)..............	1, 2, 3	20	15	65	.00	.00	.0	.0	1.00	11.87	33.25	68.25	28.60
27	Lime sulfur arsenate of lead (light)...............	1, 2, 3	34	28	38	.00	.00	.0	.0	.00	6.75	23.00	.25	2.00
28	Lime sulfur arsenate of lead (heavy)	1, 2, 3	37	20	43	.00	.00	.0	.0	.16	6.50	33.83	.66	6.00
Check B	No treatment.............	None	20	15	65	.33	1.08	.5	4.5	3.66	12.75	57.33	.00	.41

RELATIVE VALUES OF LIGHT AND HEAVY APPLICATIONS OF BORDEAUX ARSENATE OF LEAD AND LIME SULFUR ARSENATE OF LEAD

To determine the relative values of light and heavy sprayings of Bordeaux arsenate of lead and lime sulfur arsenate of lead, four plats were sprayed with these materials as shown in Table 23.

EFFECT ON FOLIAGE

The foliage on the sprayed plats was free from scab but showed a little frog-eye fungus. Late in the season Plats 25 and 26 suffered somewhat from a spray injury which took the form of brown spots. Plats 27 and 28 had healthy foliage and were free from spray injury.

EFFECT ON FRUIT

The apples from these plats were picked and examined October 9 and 10. The results are given in Table 23. The fruit from all the sprayed plats was entirely free from scab and sooty-blotch fungi. Plats 27 and 28, sprayed with lime sulfur arsenate of lead, showed almost perfect control of codling moth entering at the calyx, while Plats 25 and 26, sprayed with Bordeaux arsenate of lead, showed controls of 28 percent in the lightly sprayed plat and 73 percent in the heavily sprayed plat. The records of moths entering at the side of the apple are not considered significant because of the failure to apply sprays for the later broods. Curculio injury was reduced on all plats; in the case of the Bordeaux-sprayed plats, the reduction was larger on the heavily sprayed plat, while of the plats sprayed with lime sulfur, the reduction was inconsistently less on the heavily sprayed plat.

While no decided differences were shown between the effects of light and heavy applications in the control of fungi and insects, notable differences in the amounts of russet were observed. Heavy applications of Bordeaux seriously russeted 68.25 percent of the apples as compared with 26 percent seriously russeted by light applications. As the spray was applied with a hand pump at pressures not greater than 125 pounds, and as the same nozzles were used for both applications, the greater amount of russet can be attributed only to the greater amount of spray applied. Both of the plats sprayed with lime sulfur showed a negligible amount of russet.

SUMMARY OF RESULTS AT GRIGGSVILLE, 1913

1. Owing to the small amounts of apple scab, sooty blotch, and other fungi which appeared, it was impossible to obtain conclusive results as to the fungicidal values of the sprays used. Both Bordeaux

arsenate of lead and lime sulfur arsenate of lead gave practically complete control of scab and sooty blotch.

2. Three applications of Bordeaux arsenate of lead caused considerable foliage injury late in the season, and very seriously russeted, stunted, and distorted the fruit.

3. Lime sulfur arsenate of lead had an invigorating effect on foliage and a stimulating effect on the color and finish of the fruit.

4. Some russeting occurred as a result of single applications of Bordeaux arsenate of lead, applied either just before or two weeks after the bloom.

5. Powdered arsenate of lead gave as good results as the paste arsenate of lead.

6. Arsenate of lead used alone stimulated color and gave the fruit a good finish.

7. Various strengths of homemade lime sulfur, containing 2, 4, 6, 8, and 10 pounds of sulfur, together with 4 pounds of arsenate of lead to 100 gallons of spray, all gave satisfactory results. The 12-pound strength caused considerable injury to the foliage.

8. Copper ferrocyanide made in different ways proved useless as an insecticide when used alone.

9. Thomsen atomic sulfur arsenate of lead and Grasselli lime sulfur arsenate of lead gave equally good results in the control of fungi. Niagara soluble sulfur with arsenate of lead caused very serious foliage injury but gave highly colored fruit and satisfactorily controlled scab and sooty blotch.

10. Light spraying with Bordeaux, using 115 to 125 pounds pressure, caused less serious russet than heavy spraying at the same pressure.

11. Light and heavy spraying with lime sulfur arsenate of lead gave equally good results except in the control of curculio, for which light applications were more effective.

SPRAYING EXPERIMENTS IN 1914 AT GRIGGSVILLE, PIKE COUNTY

BY ALFRED J. GUNDERSON

OBJECTS

Spraying experiments were conducted at Griggsville, in 1914, to study the following points in summer spraying: (1) the relative values of lime sulfur and Bordeaux; (2) the value of interchanging lime sulfur and Bordeaux; (3) the value of a drenching spray, applied at the dropping of the petals, for the control of codling moth; (4) the relative values of light and heavy applications of lime sulfur arsenate of lead and Bordeaux arsenate of lead; (5) the relative values of light and heavy applications of lime sulfur arsenate of lead and Bordeaux arsenate of lead when used interchangeably; (6) the effect of reducing the strength of lime sulfur in the sprays following the second application; (7) the value of a fourth summer application; (8) the relative values of certain brands of arsenate of lead; (9) the relative values of certain proprietary lime-sulfur compounds; and (10) the fungicidal and insecticidal values of copper ferrocyanide with and without acetate of lead as an accelerating solvent.

LOCATION AND DESCRIPTION OF ORCHARD

The same block of trees was used in these experiments as that used in 1913, described on page 458. The arrangement of the plats is shown in Fig. 5, page 459.

APPARATUS AND MATERIALS

The sprays were applied with a Morrill and Morley Eclipse power sprayer at about 150 pounds pressure. Friend disc nozzles were used except for the second application on Plat 7, for which Bordeaux nozzles were used. Unless otherwise stated in the following tables, the sprays were prepared according to the methods described on pages 430 and 431.

WEATHER CONDITIONS

The weather from the middle of April thruout the summer was dry. During the fall, however, there were frequent rains. The temperature was exceptionally high during the summer months and early September.

Effect on Fungi.—The season was most unfavorable for fungous development. No scab infection appeared on any of the plats because of the dryness of the spring and early summer. Only a small amount of sooty blotch developed during the damp fall weather.

Effect on Codling Moth.—Under the hot, dry conditions prevailing during the summer, a second brood of codling moth appeared, and following it a partial third brood. Larvæ from this third brood began to enter the apples about the middle of September and continued doing damage up into picking time. In the experience of fruit growers at Griggsville an attack of third-brood codling moth had seldom, if ever, occurred, and most certainly never before in the history of the experimental work at that place. Consequently such an attack was not anticipated, and no sprays were applied against it. Sprays had been applied, however, against both the first and second broods, and these broods caused only slight damage. The third-brood moths, no doubt, came from a poorly sprayed part of the orchard not included in the experiments, in which large numbers of second-brood moths developed, producing a third brood that infested the experimental plats.

It is recognized that from 75 to 85 percent of first-brood codling moth enter the apples at the calyx end; hence the data in these experiments showing the number of larvæ entering thru the calyx would furnish an excellent criterion of the effectiveness of the sprays in controlling first-brood codling moths. Similarly, the number of larvæ entering thru the sides of the apples would, under normal conditions, furnish an excellent basis for a comparison of the effectiveness of sprays in controlling larvæ of the second-brood moths. Unfortunately, however, since the third-brood larvæ also enter thru the sides, and since the attack of this brood was more serious than that of the second brood, such comparative results as might have been observed from the effects of sprays on the second brood were largely obscured. While there are some small differences among the various plats in the number of moths entering thru the sides of the apples, these differences are not consistent nor large enough to be conclusive. In the case of the first brood, however, as indicated by the number entering thru the calyx, the results may be considered conclusive. Results showing the percentage of side injury done to apples by codling moth, tho given in the tables which follow, are not considered in the conclusions.

SPRAY DATES

All plats, with the exception of Plats 14 and 16, which were sprayed three times, received four summer applications. The dates of the applications were as follows: April 22 to 24, May 4 to 5, May 9 to 12, and July 8 to 10.

RELATIVE VALUES OF LIME SULFUR AND BORDEAUX

Experiments conducted at Griggsville during the previous three years showed lime sulfur and Bordeaux to be equally effective in the control of fungi common to that locality. Furthermore, it was demonstrated that trees sprayed with lime sulfur arsenate of lead produced fruit of higher color and better finish and had better foliage than those sprayed with Bordeaux arsenate of lead. The effects of these two sprays were again compared in 1914, when two plats were treated as shown in Table 24.

EFFECT ON FOLIAGE

The leaves of the trees sprayed with lime sulfur arsenate of lead showed a slight amount of spray injury which appeared in the form of tip and edge burning. Spray injury caused by Bordeaux arsenate of lead appeared as small brown spots on the foliage. The foliage of the plat sprayed with lime sulfur arsenate of lead was denser and more vigorous than that of the plat sprayed with Bordeaux arsenate of lead, which suffered from frequent epidemics of yellow-leaf.

EFFECT ON FRUIT

The apples from these plats were picked and examined October 12, with the results presented in Table 24. These data show that, while the unsprayed fruit had 1.75 percent serious and 23.25 percent slight sooty blotch, both Bordeaux arsenate of lead and lime sulfur arsenate of lead completely controlled the infection. Sooty blotch was confined entirely to the unsprayed fruit hanging near the ground and was due to frequent fall rains, which created favorable conditions for the development of this disease. The unsprayed fruit had 10.25 percent calyx injury caused by first-brood codling moth; Plat 2, sprayed with lime sulfur arsenate of lead, had .75 percent of this injury; and Plat 1, sprayed with Bordeaux arsenate of lead, 1.25 percent. The check plat showed 23.25 percent serious curculio injury as compared with 6.75 percent on Plat 1 and 4.5 percent on Plat 2.

A marked difference in the effects of the two sprays upon the fruit is shown in the russet columns. Plat 1, sprayed with Bordeaux arsenate of lead, showed 24.75 percent serious and 61 percent slight russet, as compared with .25 percent serious and 3 percent slight russet on Plat 2, sprayed with lime sulfur arsenate of lead. Reference to the amount of russet on the unsprayed row will show that 1.25 percent serious and 2.25 percent slight russet may have been caused by something other than the sprays. Since these amounts were present on the unsprayed trees, the indications are that lime sulfur arsenate of lead was not responsible for the russet recorded. By the same reasoning it would also appear that 23.5 percent serious and 58.75 percent slight russet in Plat 1 was caused by Bordeaux.

The apples from the plat sprayed with lime sulfur arsenate of lead were the only ones affected by burning. This injury followed within two days after the fourth application, which was made July 8.

The temperature at the time of this application was 99° F. When first noticed the injury appeared as black, sunken areas the size of a half dollar, and was confined to fruit on certain limbs. Tho it seemed then that considerable injury had been done, by picking time only a small percentage of the fruit showed the effect of burning.

Heavy applications of lime sulfur arsenate of lead applied as late as July and August are usually followed by burning, especially if the weather is very warm. The absence of the pubescence characteristic of apples earlier in the season permits the spray to run together over the smooth surface of the apples and collect in one spot. The material so collected dries quickly in hot sunlight and becomes so caustic that injury to the skin results. Heavy spraying has been safely done, however, as late as three weeks following the bloom, even during hot weather. The absence of any resulting injury was in all probability due to the pubescent condition of the fruit. Plat 2 was sprayed thoroly but not heavily early in July. In spite of the care exerted, some of the fruit received more material than was intended and some burn resulted.

Plat 2, sprayed with lime sulfur arsenate of lead, had 65 percent No. 1's as compared with 51 percent in Plat 1, which was sprayed with Bordeaux arsenate of lead. Bordeaux russet was responsible for most of the difference. The apples sprayed with Bordeaux arsenate of lead were poorly colored and had a rough finish, while those sprayed with lime sulfur arsenate of lead were highly colored, smooth, and waxy.

VALUE OF INTERCHANGING LIME SULFUR AND BORDEAUX AS SUMMER SPRAYS

In order to obtain additional information on the value of interchanging lime sulfur and Bordeaux as summer sprays, plats were sprayed as shown in Table 25.

EFFECT ON FOLIAGE

The foliage of Plats 3, 4, and 5 showed a small amount of spray injury in the form of brown spots caused by the Bordeaux and as tip and edge burning caused by the lime sulfur. All three plats suffered from an attack of yellow-leaf which slightly reduced the amount of foliage.

EFFECT ON FRUIT

The apples from these plats were picked and examined October 12, with the results presented in Table 25. Sooty blotch was perfectly controlled by all the sprays. Calyx injury from codling moth was materially reduced on all plats. The unsprayed row showed 23.25 per-

TABLE 24.—EFFECTS OF BORDEAUX AND LIME SULFUR IN COMBINATION WITH ARSENATE OF LEAD, IN THE EXPERIMENTS AT GRIGGSVILLE, 1914

Plat	Treatment	Applications	Picked apples					Percentage of picked apples affected by—								
			Total No.	Total bu.	Percentage grades			Sooty blotch		Codling moth		Curculio	Russet		Burn	
					No. 1	No. 2	Culls	Serious	Slight	Calyx	Side	Serious	Serious	Slight	Serious	Slight
1	Bordeaux arsenate of lead.....	1, 2, 3, 4	1821	10.3	51	21	28	.00	.00	1.25	13.00	6.75	24.75	61.00	.00	.00
2	Lime sulfur arsenate of lead..	1, 2, 3, 4	3456	21.8	65	16	19	.00	.00	.75	5.50	4.50	.25	3.00	.75	1.75
Check A	No treatment...............	None	1918	14.1	50	8	42	1.75	23.25	10.25	21.25	23.25	1.25	2.25	.00	.00

TABLE 25.—EFFECTS OF USING BORDEAUX FOR SOME APPLICATIONS AND LIME SULFUR FOR OTHER APPLICATIONS, IN THE EXPERIMENTS AT GRIGGSVILLE, 1914

Plat	Treatment	Applications	Picked apples					Percentage of picked apples affected by—								
			Total No.	Total bu.	Percentage grades			Sooty blotch		Codling moth		Curculio	Russet		Burn	
					No. 1	No. 2	Culls	Serious	Slight	Calyx	Side	Serious	Serious	Slight	Serious	Slight
1	Bordeaux arsenate of lead...	1, 2, 3, 4	1821	10.3	51	21	28	.00	.00	1.25	13.00	6.75	24.75	61.00	.00	.00
2	Lime sulfur arsenate of lead.	1, 2, 3, 4	3456	21.8	65	16	19	.00	.00	.75	5.50	4.50	.25	3.00	.75	1.75
3	Bordeaux arsenate of lead...	1, 4														
	Lime sulfur arsenate of lead .	2, 3	2160	13.7	70	14	16	.00	.00	.50	8.50	4.75	2.00	19.50	.00	.00
4	Lime sulfur arsenate of lead .	1, 2, 3														
	Bordeaux arsenate of lead...	4	2731	16.3	70	16	14	.00	.00	.25	7.75	2.75	.75	2.75	.00	.00
5	Bordeaux arsenate of lead...	1														
	Lime sulfur arsenate of lead .	2, 3, 4	2749	18.2	67	15	18	.00	.00	.25	12.50	2.25	3.25	19.25	7.00	3.00
Check A	No treatment.............	None	1918	14.1	50	8	42	1.75	23.25	10.25	21.25	23.25	1.25	2.25	.00	.00

cent serious injury from curculio, but this, too, was effectively reduced on the sprayed plats.

As in the preceding experiment, important differences are brought out in the russet columns. The unsprayed row showed 1.25 percent serious and 2.25 percent slight russet. By subtracting these percentages from those reported under the various treatments, it will be seen that in Plat 5 Bordeaux applied at the cluster-bud stage caused 2 percent serious and 17 percent slight russet; Bordeaux applied to Plat 4 early in July caused practically no russet; and the Bordeaux applied to Plat 3 at the cluster-bud stage and again early in July caused .75 percent serious and 17.25 percent slight russet. Bordeaux, then, russeted the fruit when applied just before the bloom, but not when applied as late as July 8, more than two months after the bloom.

Plat 5 showed 7 percent serious and 3 percent slight burn. This followed applications of lime sulfur arsenate of lead made July 8 with the temperature at 99° F. and above.

Plats 2, 3, 4, and 5 had good percentages of No. 1 apples. The apples from Plats 3 and 5 had a rough finish due to slight russet, but showed fair color, while those from Plat 4 had better color and finish. It was clearly demonstrated, from the appearance of the fruit on the trees, that the less frequently Bordeaux arsenate of lead was used before July 1, the better the color and finish of the apples.

VALUE OF A DRENCHING SPRAY, APPLIED AT THE DROPPING OF THE PETALS, FOR THE CONTROL OF CODLING MOTH

Early in the spring an Illinois apple grower requested that further tests be made of the value of a drenching spray applied at the dropping of the petals for the control of codling moth. In the following experiment this method was tested and compared with an ordinary thoro spraying. The spray schedule for the plats thus treated is shown in Table 26. Bordeaux nozzles were used for the drenching spray and Friend disc nozzles for the ordinary thoro spraying.

EFFECT ON FOLIAGE

With the exception of a slight amount of spray injury, the foliage of both sprayed plats was good.

EFFECT ON FRUIT

The fruit from these plats was picked and examined October 13 and 14, with the results presented in Table 26. Plats 7 and 3 were entirely free from sooty blotch. Plat 7 showed 5.5 percent calyx injury from codling moth as compared with .5 percent of the same injury on Plat 3 and 10.25 percent on the unsprayed row. The greater infestation of codling moth on Plat 7, where the drenching spray was

TABLE 26.—EFFECTS OF A DRENCHING SPRAY APPLIED FOR CODLING MOTH IMMEDIATELY AFTER THE FALL OF THE PETALS, IN THE EXPERIMENTS AT GRIGGSVILLE, 1914

Plat	Treatment	Applications	Picked apples					Percentage of picked apples affected by—									
			Total No.	Total bu.	Percentage grades			Sooty blotch		Codling moth		Curculio	Russet		Burn		
					No. 1	No. 2	Culls	Serious	Slight	Calyx	Side	Serious	Serious	Slight	Serious	Slight	
7	Bordeaux arsenate of lead	1, 4															
	Lime sulfur arsenate of lead (drenching spray)	2															
	Lime sulfur arsenate of lead	3	2234	14.5	69	11	20	.00	.00	5.50	20.25	.75	.50	24.00	0	0	
3	Bordeaux arsenate of lead	1, 4															
	Lime sulfur arsenate of lead (ordinary thoro spray)	2															
	Lime sulfur arsenate of lead	3	2160	13.7	70	14	16	.00	.00	.50	8.50	4.75	2.00	19.50	0	0	
Check A	No treatment	None	1918	14.1	50	8	42	1.75	23.25	10.25	21.25	23.25	1.25	2.25	0	0	

TABLE 27.—EFFECTS OF LIGHT AND HEAVY APPLICATIONS OF BORDEAUX AND LIME SULFUR, IN THE EXPERIMENTS AT GRIGGSVILLE, 1914

Plat	Treatment	Applications	Picked apples					Percentage of picked apples affected by—									
			Total No.	Total bu.	Percentage grades			Sooty blotch		Codling moth		Curculio	Russet		Burn		
					No. 1	No. 2	Culls	Serious	Slight	Calyx	Side	Serious	Serious	Slight	Serious	Slight	
8	Bordeaux arsenate of lead (heavy)	1, 2, 3, 4	1556	9.8	62	14	24	.00	.00	1.00	23.00	1.00	31.50	64.00	0	.00	
11	Bordeaux arsenate of lead (light)	1, 2, 3, 4	1739	12.8	72	11	17	.00	.00	1.25	11.75	3.00	3.25	51.00	0	.00	
9	Lime sulfur arsenate of lead (heavy)	1, 2, 3, 4	1265	10.2	71	7	22	.00	.00	.25	17.50	1.25	1.25	1.25	12	6.75	
12	Lime sulfur arsenate of lead (light)	1, 2, 3, 4	2159	14.8	77	9	14	.00	.00	.75	13.00	1.25	.75	3.00	4	3.00	
Check A	No treatment	None	1918	14.1	50	8	42	1.75	23.25	10.25	21.25	23.25	1.25	2.25	0	.00	

used, may have been due to the ineffectiveness of the spray, which was applied at the dropping of the petals and for which Bordeaux nozzles were used. The pressure was less than 100 pounds, while in the case of Plat 3, sprayed at the same time but with Friend nozzles, the pressure remained at 150 pounds. The low pressure and the coarse spray resulting from the use of the Bordeaux nozzles may have prevented proper penetration into the calyx ends of the apples. The drenching spray, however, proved more effective in the control of curculio. While the infestation was greatly reduced by both sprays, the injury from this insect in Plat 7 was negligible.

In the preceding experiment it was shown that while Bordeaux applied at the cluster-bud stage caused russet, no such injury resulted from applications made early in July. By subtracting the amount of russet recorded for the check trees from that recorded for Plats 7 and 3, it is again shown that some russeting may result from an application of Bordeaux applied just before the bloom. The color of the fruit from both plats was good, but the finish was somewhat rough on account of a slight russet.

RELATIVE VALUES OF LIGHT AND HEAVY APPLICATIONS OF LIME SULFUR ARSENATE OF LEAD AND BORDEAUX ARSENATE OF LEAD

The relative values of light and heavy spraying with lime sulfur arsenate of lead and Bordeaux arsenate of lead were tested on plats which were sprayed as shown in Table 27.

EFFECT ON FOLIAGE

The foliage of Plat 8, sprayed heavily with Bordeaux arsenate of lead, was reduced considerably by spray injury and by two epidemics of yellow-leaf. Plat 9, receiving heavy applications of lime sulfur arsenate of lead, showed considerable tip and edge burning. Plats 11 and 12, on the other hand, receiving light applications of Bordeaux arsenate of lead and lime sulfur arsenate of lead, respectively, showed very little spray injury and had excellent foliage.

EFFECT ON FRUIT

The fruit from these plats was picked and examined October 14 and 15, with the results presented in Table 27. Sooty blotch was completely controlled by all the sprays. Calyx injury from codling moth was practically the same for all four plats; a considerable reduction from the injury recorded for the unsprayed row was shown. Curculio injury was effectively and almost equally reduced on all the plats in this group.

When the russet percentages of the check plat are subtracted from the percentages of Plats 8 and 11, it is shown that the Bordeaux caused 30.25 percent serious and 61.75 percent slight russet on Plat 8, and 2 percent serious and 48.75 percent slight russet on Plat 11. Since all the sprays on both plats were applied at about 150 pounds pressure and under the same conditions, these results indicate that the amount and the severity of the russet depended upon the quantity of Bordeaux used. Deducting the amount of russet recorded for the unsprayed plat from that recorded for Plats 9 and 12, shows that the lime sulfur arsenate of lead used in these plats caused no russet.

The percentage of burn caused by the lime sulfur arsenate of lead was greater where the heavier applications were made. The fact that the burn occurred on both plats soon after the fourth spray, applied early in July during very hot weather, would indicate that if lime sulfur is applied either heavily or lightly late in the season when the temperature is near 100° F., some burning will result. The amount of burning will depend upon the quantity of material applied. Spraying so as not to permit the material to collect in drops seems to be the best way to avoid this burn.

Plat 12 had the highest percentage of No. 1 apples; the percentages of Plats 9 and 11 were almost as high and practically equal. In Plat 8 the percentage was reduced by the serious russet present. The fruit from Plats 9 and 12 had excellent color and finish, while that from Plats 8 and 11, because of russet, lacked these qualities.

RELATIVE VALUES OF LIGHT AND HEAVY APPLICATIONS OF LIME SULFUR ARSENATE OF LEAD AND BORDEAUX ARSENATE OF LEAD USED INTERCHANGEABLY

The relative values of light and heavy applications of lime sulfur arsenate of lead and Bordeaux arsenate of lead when used interchangeably were tested on two plats treated as shown in Table 28.

EFFECT ON FOLIAGE

Both plats showed some spray injury, Plat 10, which received the heavy spraying, having slightly more than Plat 13.

EFFECT ON FRUIT

The fruit from these plats was picked and examined October 14 and 15, with the results presented in Table 28. Both plats were entirely free from sooty blotch. Curculio and codling-moth injuries were slightly greater on Plat 13 than on Plat 10, altho damage from both insects was materially reduced on these plats, as shown by comparison with that on the unsprayed row.

According to results obtained by subtracting the percentages for the check plat from those for the sprayed plats, Plat 10 had 4.75 percent serious and 19.25 percent slight russet, and Plat 13 had 11.75

percent slight russet caused by the sprays. It is evident here, as in the preceding experiment, that the amount and severity of the russet were regulated by the amount of spray applied, since all the applications were made at the same pressure.

The effect of the different treatments is not brought out in the grade columns, where the percentages are practically the same for both plats. The color of the fruit from these plats was good, but finish was lacking because of russet.

EFFECT OF GRADUALLY REDUCING THE STRENGTH OF LIME SULFUR AFTER THE SECOND APPLICATION

The effects of gradually reducing the strength of the lime sulfur in applications of lime sulfur arsenate of lead, following the second spraying, were tested as shown in Table 29. These were compared in turn with the effects of lime sulfur used at the same strength thruout the season in combination with arsenate of lead.

EFFECT ON FOLIAGE

The foliage of both sprayed plats showed some lime-sulfur injury in the form of tip and edge burning; otherwise the foliage was good.

EFFECT ON FRUIT

The fruit from these plats was picked and examined October 12 and 13, with the results presented in Table 29. Both sprayed plats were entirely free from sooty blotch. Codling-moth calyx injury was almost equally well controlled by both sprays. Curculio was more effectively controlled on Plat 6, where different strengths of lime sulfur were used, than on Plat 2, where the same strength was used thruout the season. Both treatments, however, greatly reduced curculio infestation, as is indicated by the infestation on the unsprayed row. The russet shown on Plats 2 and 6 could not have been caused by the spray, because practically the same amount was present on the unsprayed apples. The amount of burn, which was small, was practically equal on both plats. This injury followed soon after the fourth application, made early in July on an extremely warm day. In spite of the care taken to spray the trees thoroly but not heavily, a few branches received too much spray, and the fruit on these suffered from burn. The percentage of No. 1 apples was greater on Plat 6 than on Plat 2. The fruit of both plats had excellent color and finish.

VALUE OF A FOURTH SUMMER APPLICATION

With the object of determining the value of a fourth summer application, four plats were sprayed as shown in Table 30.

TABLE 28.—EFFECTS OF LIGHT AND HEAVY APPLICATIONS OF BORDEAUX AND LIME SULFUR WHERE BOTH WERE USED IN THE SAME SPRAY SCHEDULE, IN THE EXPERIMENTS AT GRIGGSVILLE, 1914

Plat	Treatment	Applications	Picked apples					Percentage of picked apples affected by—								
			Total No.	Total bu.	Percentage grades			Sooty blotch		Codling moth		Curculio	Russet		Burn	
					No. 1	No. 2	Culls	Serious	Slight	Calyx	Side	Serious	Serious	Slight	Serious	Slight
10	Bordeaux arsenate of lead (heavy)	1, 4														
	Lime sulfur arsenate of lead (heavy)	2, 3	1409	10.3	77	9	14	.00	.00	2.25	12.75	1.00	6.00	21.50	0	0
13	Bordeaux arsenate of lead (light)	1, 4														
	Lime sulfur arsenate of lead (light)	2, 3	1858	14.1	75	9	16	.00	.00	3.00	15.25	4.75	.75	14.00	0	0
Check A	No treatment	None	1918	14.1	50	8	42	1.75	23.25	10.25	21.25	23.25	1.25	2.25	0	0

TABLE 29.—EFFECTS OF GRADUALLY REDUCING THE STRENGTH OF LIME SULFUR AFTER THE SECOND APPLICATION, IN THE EXPERIMENTS AT GRIGGSVILLE, 1914

Plat	Treatment	Applications	Picked apples					Percentage of picked apples affected by—								
			Total No.	Total bu.	Percentage grades			Sooty blotch		Codling moth		Curculio	Russet		Burn	
					No. 1	No. 2	Culls	Serious	Slight	Calyx	Side	Serious	Serious	Slight	Serious	Slight
2	Lime sulfur arsenate of lead (1 in 20)	1, 2, 3, 4	3456	21.8	65	16	19	.00	.00	.75	5.50	4.50	.25	3.00	.75	1.75
6	Lime sulfur arsenate of lead (1 in 20)	1, 2														
	Lime sulfur arsenate of lead (1 in 40)	3														
	Lime sulfur arsenate of lead (1 in 50)	4	2331	15.1	71	14	15	.00	.00	1.25	11.25	1.00	1.50	.50	1.00	1.25
Check A	No treatment	None	1918	14.1	50	8	42	1.75	23.25	10.25	21.25	23.25	1.25	2.25	.00	.00

TABLE 30.—EFFECTS OF A FOURTH SUMMER APPLICATION, IN THE EXPERIMENTS AT GRIGGSVILLE, 1914

Plat	Treatment	Applications	Picked apples					Percentage of picked apples affected by—								
			Total No.	Total bu.	Percentage grades			Sooty blotch		Codling moth		Curculio	Russet		Burn	
					No. 1	No. 2	Culls	Serious	Slight	Calyx	Side	Serious	Serious	Slight	Serious	Slight
2	Lime sulfur arsenate of lead .	1, 2, 3, 4	3456	21.8	65	16	19	.00	.00	.75	5.50	4.50	.25	3.00	.75	1.75
16	Lime sulfur arsenate of lead. .	1, 2, 3	2171	16.8	80	6	14	.00	.00	1.00	12.25	2.75	.25	1.00	.00	.00
3	Bordeaux arsenate of lead. . . Lime sulfur arsenate of lead.	1, 4 2, 3	2160	13.7	70	14	16	.00	.00	.50	8.50	4.75	2.00	19.50	.00	.00
14	Bordeaux arsenate of lead. . . Lime sulfur arsenate of lead.	1 2, 3	2302	16.4	71	11	18	.00	.00	.00	18.75	3.00	3.25	16.50	.00	.00
Check A	No treatment.	None	1918	14.1	50	8	42	1.75	23.25	10.25	21.25	23.25	1.25	2.25	.00	.00

EFFECT ON FOLIAGE

The foliage of Plats 14 and 16, which did not receive a fourth application, was practically free from spray injury, while that of Plat 2 showed some injury caused by the fourth application. So far as the foliage was concerned the fourth application of Bordeaux arsenate of lead and lime sulfur arsenate of lead did more harm than good.

EFFECT ON FRUIT

The fruit from these plats was picked and examined October 12 and 19, with the results presented in Table 30. Sooty blotch was completely controlled on all plats. Codling-moth calyx injury was completely controlled on Plat 14 and effectively controlled on the other sprayed plats. Curculio infestation was also effectively reduced.

Comparison of the russet percentages of the sprayed plats with those of the check plat shows that the russet on Plats 2 and 16 was caused by something other than the sprays. Plat 3, however, had .75 percent serious and 17.25 percent slight russet, and Plat 14 had 2 percent serious and 14.25 percent slight russet caused by the Bordeaux. It has been previously stated that Bordeaux does not russet fruit when applied as late in the season as July. Since the amount of russet on Plats 3 and 14 is practically equal, it is again shown that the fourth spray of Bordeaux did not cause russet.

Plat 2, which received four applications of lime sulfur arsenate of lead, had .75 percent serious and 1.75 percent slight burn. Since no burn was found on the fruit of Plat 16, which received only three sprays of this material, the injury on Plat 2 must have resulted from the fourth application, made in July.

All four sprayed plats had a good percentage of No. 1 apples. The fruit from Plats 2 and 16 had better color and finish than that from Plats 3 and 14, because of the absence of Bordeaux russet.

These experiments showed that a fourth application of Bordeaux arsenate of lead was of no value; that a fourth application of lime sulfur arsenate of lead caused burn; and that three applications of lime sulfur arsenate of lead gave equally good results in controlling sooty blotch and caused no injury to the fruit.

RELATIVE VALUES OF CERTAIN BRANDS OF ARSENATE OF LEAD

In this experiment certain brands of arsenate of lead were tested on plats treated as shown in Table 31.

EFFECT ON FOLIAGE

The foliage of these plats showed some burning caused by Bordeaux and lime sulfur arsenate of lead.

TABLE 31.—EFFECTS OF DIFFERENT BRANDS OF ARSENATE OF LEAD, IN THE EXPERIMENTS AT GRIGGSVILLE, 1914

Plat	Treatment	Applications	Picked apples					Percentage of picked apples affected by—								
			Total No.	Total bu.	Percentage grades			Sooty blotch		Codling moth		Curculio	Russet		Burn	
					No. 1	No. 2	Culls	Serious	Slight	Calyx	Side	Serious	Serious	Slight	Serious	Slight
3	Bordeaux Grasselli paste arsenate of lead (4-100)	1, 4														
	Lime sulfur Grasselli paste arsenate of lead (4-100)	2, 3	2160	13.7	70	14	16	.0	0	.50	8.50	4.75	2.00	19.50	0	0
17	Bordeaux Corona powdered arsenate of lead (2-100)	1, 4														
	Lime sulfur Corona powdered arsenate of lead (2-100)	2, 3	2111	15.0	79	11	10	.0	0	.25	11.00	3.00	4.25	20.25	0	0
18	Bordeaux Corona powdered arsenate of lead (4-100)	1, 4														
	Lime sulfur Corona powdered arsenate of lead (4-100)	2, 3	2380	19.0	80	10	10	.0	0	1.00	10.25	5.00	3.00	21.50	0	0
19	Bordeaux Ansbacher paste arsenate of lead (4-100)	1, 4														
	Lime sulfur Ansbacher paste arsenate of lead (4-100)	2, 3	2206	15.8	78	10	12	.0	0	.25	15.00	3.50	2.00	18.50	0	0
20	Bordeaux Dow paste arsenate of lead (4-100)	1, 4														
	Lime sulfur Dow paste arsenate of lead (4-100)	2, 3	1380	11.1	69	10	21	.0	0	1.75	17.25	10.00	4.00	17.75	0	0
21	Bordeaux Sherwin-Williams paste arsenate of lead (4-100)	1, 4														
	Lime sulfur Sherwin-Williams paste arsenate of lead (4-100)	2, 3	1511	11.9	52	12	36	.0	0	2.75	35.75	12.00	3.75	20.75	0	0
22	Bordeaux Sherwin-Williams powdered arsenate of lead (2-100)	1, 4														
	Lime sulfur Sherwin-Williams powdered arsenate of lead (2-100)	2, 3	2303	17.3	66	9	25	.0	0	.00	25.25	9.50	2.25	15.75	0	0
23	Bordeaux Thomsen paste arsenate of lead (4-100)	1, 4														
	Lime sulfur Thomsen paste arsenate of lead (4-100)	2, 3	2401	15.6	70	12	18	.0	0	.25	17.50	6.75	4.00	23.75	0	0
Check B	No treatment	None	972	7.7	33	8	59	.5	8	11.50	36.50	33.75	1.00	2.00	0	0

EFFECT ON FRUIT

The fruit from these plats was picked and examined October 19 and 20. As shown in Table 31, the fruit of the sprayed plats was entirely free from sooty blotch. The unsprayed row showed 11.5 percent codling-moth calyx injury. Grasselli paste arsenate of lead (4-100) reduced this injury to .5 percent; Corona powdered arsenate of lead (2-100) to .25 percent; Corona powdered arsenate of lead (4-100) to 1 percent; Ansbacher paste arsenate of lead (4-100) to .25 percent; Dow paste arsenate of lead (4-100) to 1.75 percent; Sherwin-Williams paste arsenate of lead (4-100) to 2.75 percent; Sherwin-Williams powdered arsenate of lead (2-100) controlled it completely; and Thomsen paste arsenate of lead (4-100) reduced it to .25 percent. All the arsenates of lead reduced curculio infestation.

All sprayed plats showed some russet from the first application of Bordeaux, but all, with the exception of Plat 21, had a good percentage of No. 1 apples. The apples in Plat 21 were most severely damaged by the partial third brood of codling moth. The color of the fruit was good on all plats, but the finish was rough.

Relative Values of Certain Proprietary Lime-sulfur Compounds

The relative values of Niagara soluble sulfur, Thomsen atomic sulfur, and lime sulfur were tested as shown in Table 32.

EFFECT ON FOLIAGE

Lime sulfur arsenate of lead caused some tip and edge burning on the foliage of Plat 15. Injury from Niagara soluble sulfur arsenate of lead, together with an epidemic of yellow-leaf, reduced the amount of foliage in Plat 24. The foliage of Plat 25, sprayed with Thomsen atomic sulfur, was excellent; it showed but a negligible amount of tip and edge burning.

EFFECT ON FRUIT

The fruit from these plats was picked and examined October 19 and 21, with the results presented in Table 32. As in the preceding experiments, all the sprayed plats were entirely free from sooty blotch. Codling-moth calyx injury was reduced from 11.5 percent on the unsprayed row to .5 percent on Plat 15, .25 percent on Plat 24, and 1 percent on Plat 25. Considerable burning of the fruit occurred on Plat 15, and some on Plats 24 and 25. The injury in each case followed the fourth application, made during the hot weather of early July, and appeared only on the fruit of certain branches which had received a little too much spray. The fruit of all three plats possessed excellent color and finish. That of Plat 24, however, excelled all other fruit in the orchard with respect to color. A good percentage of No. 1 apples was obtained from each plat.

TABLE 32.—EFFECTS OF PROPRIETARY SULFUR SPRAYS, IN THE EXPERIMENTS AT GRIGGSVILLE, 1914

Plat	Treatment	Applications	Picked apples					Percentage of picked apples affected by—								
			Total No.	Total bu.	Percentage grades			Sooty blotch		Codling moth		Curculio	Russet		Burn	
					No. 1	No. 2	Culls	Serious	Slight	Calyx	Side	Serious	Serious	Slight	Serious	Slight
15	Grasselli lime sulfur arsenate of lead (2-4-100)........	1, 2, 3, 4	2059	14.4	70	11	19	.0	0	.50	9.50	4.25	.75	2.00	9.50	9.00
24	Niagara soluble sulfur arsenate of lead (2-4-100) ..	1, 2, 3, 4	3013	19.4	75	11	14	.0	0	.25	6.75	3.50	.75	.25	3.50	2.75
25	Thomsen atomic sulfur arsenate of lead (14-4-100) ..	1, 2, 3, 4	2763	17.8	69	11	20	.0	0	1.00	10.75	2.75	1.75	1.50	2.25	2.50
Check B	No treatment	None	972	7.7	33	8	59	.5	8	11.50	36.50	33.75	1.00	2.00	.00	.00

TABLE 33.—EFFECTS OF COPPER FERROCYANIDE WITH AND WITHOUT ACETATE OF LEAD, IN THE EXPERIMENTS AT GRIGGSVILLE, 1914

Plat	Treatment	Applications	Picked apples					Percentage of picked apples affected by—								
			Total No.	Total bu.	Percentage grades			Sooty blotch		Codling moth		Curculio	Russet		Burn	
					No. 1	No. 2	Culls	Serious	Slight	Calyx	Side	Serious	Serious	Slight	Serious	Slight
26	Copper ferrocyanide arsenate of lead (2-2-4-100)	1, 2, 3, 4	1957	12.9	70	11	19	.0	0	1.25	16.25	5.25	2.00	2.0	0	0
27	Copper ferrocyanide acetate of lead arsenate of lead (2-2½-4-100)	1, 2, 3, 4	1840	12.5	64	12	24	.0	0	1.00	13.75	18.50	.75	.0	0	0
28	Copper ferrocyanide acetate of lead (2-2½-100).......	1, 2, 3, 4	998	7.0	36	10	54	.0	0	7.50	38.75	24.00	.25	.5	0	0
Check B	No treatment	None	972	7.7	33	8	59	.5	8	11.50	36.50	33.75	1.00	2.0	0	0

FUNGICIDAL AND INSECTICIDAL VALUES OF COPPER FERROCYANIDE WITH AND WITHOUT ACETATE OF LEAD AS AN ACCELERATING SOLVENT

The results of past experiments with copper ferrocyanide showed it to be practically useless either as a fungicide or as an insecticide. This ineffectiveness may be explained by the fact that copper ferrocyanide is very insoluble. It was suggested that the addition of an accelerating solvent, such as acetate of lead, might make this compound sufficiently soluble to be effective. Accordingly, three plats were treated as shown in Table 33.

EFFECT ON FOLIAGE

The foliage of Plats 26 and 27 was by far the best in the orchard, from the standpoint of both color and size. The leaves possessed a dark green, velvety appearance. The foliage of Plat 28 was excellent but not equal to that of Plats 26 and 27.

EFFECT ON FRUIT

The fruit from these plats was picked and examined October 21 and 22, with the results presented in Table 33. The absence of sooty blotch in Plats 26, 27, and 28 may have been due to the fact that these plats were situated on higher and drier ground than the unsprayed trees. Codling-moth calyx injury was almost equally reduced on Plats 26 and 27 by the action of the arsenate of lead. On Plat 28, however, this injury was not much less than on the unsprayed row. Curculio injury was effectively reduced on Plat 26. The greater injury from this insect shown in Plat 27 may be explained by the fact that this plat was situated near a clump of woods and underbrush. It has been the experience of the writer that when even thoroly sprayed trees are situated in close proximity to a woods or a brush heap, they suffer more from curculio than those in the open. The sprays applied to Plat 28 reduced curculio infestation only slightly.

Plats 26 and 27 had fruit of higher color and better finish than did Plat 28, probably owing to the arsenate of lead in the sprays. Plats 26 and 27 far surpassed Plat 28 in the percentage of No. 1 apples. Plat 28 and the unsprayed row had about equal percentages.

SUMMARY OF RESULTS AT GRIGGSVILLE, 1914

1. Climatic conditions at Griggsville in 1914 were unfavorable to scab development but favorable to codling-moth infestation.
2. Codling-moth calyx injury was greatly reduced on all plats where arsenate of lead was used. Because of severe infestation from a partial third brood of this insect entering thru the sides of the apples just prior to picking time, the effectiveness of the sprays in controlling second-brood codling-moth larvæ was largely obscured.

3. Sooty-blotch infection was small; it was completely controlled.

4. Serious russeting of the fruit resulted from Bordeaux applied about a week after the bloom. Some russeting resulted from the cluster-bud application of the same material, but none from an application made early in July.

5. Both Bordeaux arsenate of lead and lime sulfur arsenate of lead caused foliage injury, the former causing more serious injury than the latter.

6. Lime sulfur arsenate of lead applied on hot days early in July caused some burn. Early applications, however, did not.

7. Apples sprayed with lime sulfur arsenate of lead had better finish and color than those sprayed with Bordeaux arsenate of lead.

8. Interchanging lime sulfur arsenate of lead and Bordeaux arsenate of lead, except when three applications of lime sulfur arsenate of lead were followed by one of Bordeaux arsenate of lead early in July, proved unsatisfactory, owing to the increased amount of russet.

9. A drenching spray under low pressure applied at the fall of the bloom proved unsatisfactory in the control of codling moth.

10. The severity and the amount of Bordeaux russet depended upon the quantity of spray used.

11. A heavy application of lime sulfur arsenate of lead applied early in July caused more serious burn than a light application applied at the same time. There was no difference in this respect between light and heavy applications made earlier in the season.

12. Heavy applications of lime sulfur arsenate of lead and of Bordeaux arsenate of lead used interchangeably proved less satisfactory than light applications made at the same times, owing to the better color and finish of the lightly sprayed fruit.

13. No particular advantage was gained by gradually reducing the strength of lime sulfur in the applications of lime sulfur arsenate of lead following the second spraying; 1-in-20 homemade lime sulfur caused practically the same amount of burn as 1-in-50 homemade lime sulfur when applied early in July.

14. Three applications of lime sulfur arsenate of lead proved more satisfactory than four applications of either lime sulfur arsenate of lead or Bordeaux arsenate of lead.

15. All brands of arsenate of lead tested reduced codling-moth injury effectively.

16. Niagara soluble sulfur, Grasselli lime sulfur, and Thomsen atomic sulfur combined with arsenate of lead caused some burning of the fruit when applied early in July. The soluble sulfur seriously injured the foliage; the other two sprays caused but slight injury.

17. No data were secured on the fungicidal value of copper ferrocyanide with and without acetate of lead. The data on the insecticidal value of this spray indicate that it is too slight in effect to be of commercial significance.

GENERAL SUMMARY

BY B. S. PICKETT

The field experiments in spraying in 1913 and 1914, having been performed with a view to solving certain definite problems, are summarized in the form of answers to specific questions suggested directly or indirectly by the general considerations discussed in the introduction to this bulletin.

SUMMARY OF DATA

1. *What is the general effectiveness of applications of standard spray mixtures, including Bordeaux, lime sulfur, and arsenate of lead, in the control of fungi and insects affecting the apple crop?*

In summarizing the data for the field experiments during the years 1909 to 1912,[1] the writer, in answering a similar question, made the following statement:

> "No fact stands out more distinctly in a study of the data presented in the reports included in this bulletin than the general effectiveness of spraying over no spraying. Even under the most unfavorable circumstances, some degree of benefit has resulted from the application of all the standard sprays in every series of experiments and in every year of the experimentation. Year after year the sprayed plats have been conspicuous by their more healthy and vigorous foliage and by the freedom of their fruit from insects and diseases."

The data obtained in 1913 and 1914 add further evidence of the effectiveness of spraying, tho the comparative freedom of some of the orchards from fungi and of others from codling moth and curculio, in one or both seasons, has resulted in obtaining fewer records than had there been more generally severe infestations of insects and infections of fungi.

Tables 34 and 35 present a summary of all the data obtained in 1913 and 1914 which bear directly on the effectiveness of Bordeaux, lime sulfur, and arsenate of lead in controlling fungous diseases and insects. At a casual glance it will be seen that in nearly all cases high degrees of control of diseases and insects prevail. In interpreting the data, however, allowances must be made for the severity of the disease infection or the insect infestation, as the case may be. When such allowances are made, the advantages of spraying become even more marked than the controls in the tables indicate.

No data on the control of apple scab or other fungous diseases where either Bordeaux or lime sulfur with arsenate of lead were used were secured at Neoga or Flora. At Neoga, apple scab did not appear during 1913 and 1914, and at Flora no tests were made of either spray alone. At Griggsville, in 1913, there was a small infection of apple

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[1] J. C. Blair et al., Ill. Agr. Exp. Sta. Bul. 185, p. 187.

TABLE 34.—EFFECTS OF BORDEAUX AND LIME SULFUR IN CONTROLLING FUNGOUS DISEASES AND IN CAUSING RUSSET AND BURN, IN FIELD EXPERIMENTS IN SPRAYING, 1913 AND 1914

Table[1]	Page	Experimenter	Place	Year	Fungicide[5]	Percentage of—							
						Scab		Sooty blotch		Blotch		Russet[6]	Burn[6]
						Infection	Control	Infection	Control	Infection	Control		
17	461	A. J. G.	Griggsville	1913	Bordeaux......	2.33	100	22.74	100	.0		87.34	
19	464	A. J. G.	Griggsville	1913	Bordeaux......	2.33	100	22.74	100	.0		85.24	
24	476	A. J. G.	Griggsville	1914	Bordeaux......	.00		25.00	100	.0		82.25	.0
27	478	A. J. G.	Griggsville	1914	Bordeaux......							50.75 to 92.0	.0
17	461	A. J. G.	Griggsville	1913	Lime sulfur....	2.33	100	22.74	100	.0		.39	.0
19	464	A. J. G.	Griggsville	1913	Lime sulfur....	2.33	100	22.74	100	.0		5.59	.0
20	464	A. J. G.	Griggsville	1913	Lime sulfur....	2.33	100	22.74	100	.0		0 to 5.61	.0
22	469	A. J. G.	Griggsville	1913	Lime sulfur....	1.41	89	5.00	100	.0		0 to 7.75	.0
24	476	A. J. G.	Griggsville	1914	Lime sulfur....	.00		25.00	100	.0		.0	2.5
30[2]	483	A. J. G.	Griggsville	1914	Lime sulfur....	.00		25.00	100	.0		.0	.0
32	487	A. J. G.	Griggsville	1914	Lime sulfur....	.00		8.50	100	.0		.0	18.5
11[3]	454	W. A. R.	Flora	1913	Lime sulfur and Bordeaux....	62.20	86 to 100	.00		56.6	43 to 93		
12[4]	454	W. A. R.	Flora	1913	Lime sulfur and Bordeaux....	34.90	93 to 99	.00		52.6	63 to 90		
18	461	A. J. G.	Griggsville	1913	Lime sulfur and Bordeaux....	2.33	100	22.74	95 to 100	.0			
25	476	A. J. G.	Griggsville	1914	Lime sulfur and Bordeaux....	.00		25.00	100	.0			
30[2]	483	A. J. G.	Griggsville	1914	Lime sulfur and Bordeaux....	.00		25.00	100	.0			
31	485	A. J. G.	Griggsville	1914	Lime sulfur and Bordeaux....	.00		8.50	100	.0			

[1] Data from Table 26 are omitted because Plat 3 is reported elsewhere and sprays were not applied to Plat 7 in standard quantities; from Table 27, with regard to scab, blotch, and sooty blotch, because applications were not made in standard quantities; from Table 28 because sprays were not applied in standard quantities; and from Table 29 because records for Plat 2 are presented in Table 24, and in Plat 6 standard dilutions were not followed.

[2] Data for Plats 2 and 3 are reported elsewhere, hence Plat 16 only is given here.

[3] Tables 13 and 15 present practically the same data and are therefore omitted.

[4] Tables 14 and 16 present practically the same data and are therefore omitted.

[5] Arsenate of lead was used with the fungicide in every case.

[6] Russet and burn data are omitted where both Bordeaux and lime sulfur were used owing to the fact that the amounts varied, depending on the arrangement of the schedule and the number of times each was used. Russet and burn data are obtained by subtracting the total russet or burn shown on the unsprayed plats from that shown on the sprayed plats in question.

TABLE 35.—EFFECTS OF ARSENATE OF LEAD USED ALONE AND IN COMBINATION WITH FUNGICIDES ON THE CONTROL OF CODLING MOTH AND CURCULIO, IN FIELD EXPERIMENTS IN SPRAYING, 1913 AND 1914

Table	Page	Experimenter	Place	Year	Percentage of—								
					Codling moth (first brood)			Codling moth (late broods)			Curculio (serious injury)		
					Infestation	Lowest control	Best control	Infestation	Lowest control	Best control	Infestation	Lowest control	Best control
1[1]	435	O. S. W.	Neoga	1913	18.00	78	94				.00		
2[1]	435	O. S. W.	Neoga	1913	18.00	22	89				.00		
3[1]	436	O. S. W.	Neoga	1913	18.00	72	83				.00		
4[2]	437	O. S. W.	Neoga	1913	32.00	78	94	52	62	73	.00		
6	443	O. S. W.	Neoga	1914	14.70	68	100	76	64	97	.00		
7	444	O. S. W.	Neoga	1914	6.00	58	83	51	82	90	.00		
12[3]	454	W. A. R.	Flora	1913	50.10	54	92				.00		
18[4]	461	A. J. G.	Griggsville	1913	2.50	-8	100				67.83	68	85
19	464	A. J. G.	Griggsville	1913	2.50	84	95				67.83	79	91
20	464	A. J. G.	Griggsville	1913	2.50	84	100				67.83	69	94
21	466	A. J. G.	Griggsville	1913	3.66	84	96				57.33	77	85
22	469	A. J. G.	Griggsville	1913	3.66	82	97				57.33	78	89
23	469	A. J. G.	Griggsville	1913	3.66	28	100				57.33	32	60
24	476	A. J. G.	Griggsville	1914	10.25	88	93	21.25	39	74	23.25	71	81
25	476	A. J. G.	Griggsville	1914	10.25	88	98	21.25	39	74	23.25	71	90
26	478	A. J. G.	Griggsville	1914	10.25	46	95	21.25	5	60	23.25	80	97
27	478	A. J. G.	Griggsville	1914	10.25	88	98	21.25	-8	45	23.25	87	96
28	482	A. J. G.	Griggsville	1914	10.25	71	78	21.25	28	40	23.25	80	96
29	482	A. J. G.	Griggsville	1914	10.25	88	93	21.25	47	74	23.25	81	96
30[5]	483	A. J. G.	Griggsville	1914	10.25	90	100				23.25	80	88
31	485	A. J. G.	Griggsville	1914	11.50	76	100	36.50	2	77	33.75	64	91
32	487	A. J. G.	Griggsville	1914	11.50	91	98	36.50	71	82	33.75	87	92
33	487	A. J. G.	Griggsville	1914	11.50	89	91	36.50	55	62	33.75	45	84

[1] Late-brood codling-moth data are omitted from Tables 1, 2, and 3 because no sprays had been applied for the control of an unexpected third brood; in Table 1, however, it is shown that controls running from 21 to 62 percent were obtained; in Table 2, controls of 30 to 52 percent; and in Table 3, controls of 38 to 44 percent.

[2] Late-brood codling-moth data are based on figures for four applications. Jonathan apples were harvested before the appearance of the third brood.

[3] Practically the same data appear also in Tables 14 and 16.

[4] The same data appear also in Table 17.

[5] Late-brood codling-moth data are omitted owing to the fact that no sprays were applied for the control of these insects on Plats 14 and 16, while the data for Plats 2 and 3 are presented elsewhere. Controls running from 12 to 42 percent were, however, obtained in Plats 14 and 16, respectively.

scab amounting in one check plat to 1.41 and in another to 2.33 percent of the crop. Both Bordeaux and lime sulfur, when used separately, completely controlled the disease except in one plat, where lime sulfur exercised a control of 89 percent. The total amount of scab in this plat amounted, however, to only .16 of one percent of the crop, an amount wholly negligible from a practical standpoint. In 1914 no apple scab appeared at Griggsville. Sooty-blotch infections running from 5 to 22.74 percent in 1913 and from 8.5 to 25 percent in 1914 were recorded for the check plats. Both Bordeaux and lime sulfur, however, when used separately, completely controlled this disease in both seasons.

Using Bordeaux and lime sulfur for different applications in the same schedule also gave excellent results in controlling fungous diseases. At Flora in 1913, where there was a serious infection of scab, amounting to 34.9 percent in one check plat and 62.2 percent in another, the combined sprays exercised controls running from 86 to 100 percent. With blotch the results were more variable but of decided importance. The infections in the check plats were 52.6 and 56.6 percent respectively, while the controls varied from 43 to 93 percent. At Griggsville, where there was a slight infection of scab in 1913, the combined sprays resulted in completely controlling the disease, while at the same place from 95 to 100 percent control of sooty blotch was obtained in 1913 and 1914.

Codling moth and curculio, as a rule, were well controlled by applications of arsenate of lead. Table 35 shows that in the entire series of experiments, the control of first-brood codling moth in the most effectively sprayed plats ranged from 78 to 100 percent. In nineteen cases out of twenty-three the control was above 90 percent. Even among the plats least effectively sprayed in each series, controls ranging up to 91 percent were obtained. In a single instance in the Griggsville experiments in 1913 one plat failed to show any control as a result of spraying, but the check-plat infestation was only 2.5 percent, and the difference between the check and the sprayed plat was but a fraction of one percent. Moreover, the most effectively sprayed plat in the same series showed a control of 100 percent.

Later broods of codling moth proved much more difficult to control; nevertheless, in the most effectively sprayed plats, controls ranging from 40 to 97 percent were obtained, while in the least effectively sprayed plats the controls ranged from -8 percent to 82 percent. In only one plat in one series did the sprays show no positive effectiveness in controlling late-brood codling moth.

No data on curculio control were obtained at Neoga or at Flora, but many records were made at Griggsville, where the infestation was sufficiently serious in both 1913 and 1914 to afford excellent opportunity for good comparisons. In 1913 the most effectively sprayed plats showed controls ranging from 60 to 94 percent and the least effectively sprayed plats from 32 to 79 percent. In 1914 the most effectively sprayed plats showed controls ranging from 81 to 97 percent and the least effectively sprayed plats from 45 to 87 percent. In no case did spraying with arsenate of lead fail to exercise a decidedly beneficial effect.

These results, taken in conjunction with those reported in Bulletin 185, establish even more firmly the advantages of spraying with standard insecticides and fungicides, over no spraying, in controlling some of the more common insects and fungi affecting apples.

2. *What are the relative values of Bordeaux and lime sulfur as sprays for the apple?*

The relative values of Bordeaux and lime sulfur are dependent upon their comparative effectiveness as fungicides and their comparative liability to injure or improve the finish of the fruit and the health and vigor of the tree. In Bulletin 185 it was concluded (page 192) that "Bordeaux and lime sulfur, properly used, are both excellent sprays for the apple." A comparison of the effects of these fungicides in 1913 and 1914 may be obtained from a study of Table 34. It will be seen that, as fungicides, Bordeaux and lime sulfur were equally effective, 100-percent control being obtained in nearly every case.

In their liability to cause injury to the fruit, marked differences between the two sprays appeared. At Griggsville, Bordeaux used alone caused russeting to a greater or less degree on from 50.75 to 92 percent of all the apples to which it was applied. No plats sprayed early in the season escaped the effects of the spray. On the other hand, lime sulfur rarely caused any russeting; its range of injury was from .39 to 7.75 percent. Bordeaux caused no burning of the fruit, while lime sulfur in one case burned 2.5 percent and in another 18.5 percent of the crop. In qualities which contribute to an attractive finish, such as smoothness, high color, and waxy skin, the fruit sprayed with lime sulfur was superior to that sprayed with Bordeaux.

The only data recorded showing a comparison of the effects of Bordeaux and lime sulfur on foliage were obtained at Griggsville. In 1913 the two sprays were equally effective in controlling leaf spot (*Sphæropsis malorum*), the only disease which appeared (page 460); in 1914 the absence of diseases afforded no opportunity for comparison (page 472). In both years the plats sprayed with lime sulfur had more vigorous foliage than those sprayed with Bordeaux (pages 460 and 474).

When all the facts are taken into consideration, it is concluded that both Bordeaux and lime sulfur are efficient fungicides; that neither is always free from injurious effects to the fruit and foliage; that lime sulfur used for sprays before July 1 is less liable to injure fruit and foliage than Bordeaux; that lime sulfur used after July 1, or during excessively hot weather, is more liable to injure the fruit than Bordeaux; that lime sulfur used thruout the season is safer than Bordeaux; and, finally, that the most desirable practice is to use lime sulfur for all the applications made in April, May, and, during cool weather, in June, and Bordeaux for applications made in July, or to omit the fungicide entirely from the July sprays, unless the season is very favorable for the development of bitter rot or other fungous diseases.

3. *Are there differences between various brands of arsenate of lead which would make one brand more efficient than another?*

Table 36 presents a summary of the effects of the different brands of arsenate of lead used in 1913 and 1914. Owing to the variation in the number of tests of the different kinds and to the seeming variations in the effects of several of the brands themselves, it is difficult to draw very definite conclusions as to their order of merit. Among the brands that gave rather distinctly inferior results were Grasselli dry, Hemingway paste, and Vreeland dry arsenates of lead. Ansbacher paste arsenate of lead, which was used in one experiment only, gave excellent results in the control of first-brood codling moth and curculio, with a somewhat inferior control of second-brood codling moth. Grasselli, Sherwin-Williams, and Thomsen triplumbic paste arsenates of lead were somewhat inconsistently variable in their effects, giving high degrees of control in some experiments and relatively low in others. The results indicated an average efficiency. In the experiments at Griggsville, Grasselli paste arsenate of lead gave better results than Sherwin-Williams paste arsenate of lead, while in the experiments at Neoga the results were reversed. Corona dry, Dow paste, and Sherwin-Williams dry arsenates of lead gave the most consistently good results of any of the brands used; each of these was tried at Neoga and Griggsville with closely corresponding effects.

4. *Of what value are certain new and proprietary fungicides?*

The new and proprietary sprays tested were copper ferrocyanide, calcium hyposulfite, Thomsen atomic sulfur, Niagara and Grasselli soluble sulfur, and Sherwin-Williams tuber tonic. The effects of these sprays in comparison with the average effects of Bordeaux and lime sulfur are shown in Table 37.

According to these results, the effects of copper ferrocyanide were not unfavorable. The complete absence of fungous diseases in some cases and the presence of only light infections in others, however, prevent drawing definite conclusions regarding the efficiency of the spray.

The fungicidal efficiency of calcium hyposulfite was not determined, owing to the absence of fungous diseases at Neoga, where the spray was used in 1914. It was reported as producing fruit of unusually high color and finish.

TABLE 36.—EFFECTS OF DIFFERENT MAKES OR BRANDS OF ARSENATE OF LEAD USED ALONE AND IN COMBINATION WITH FUNGICIDES ON THE CONTROL OF CODLING MOTH AND CURCULIO, IN FIELD EXPERIMENTS IN SPRAYING, 1913 AND 1914

Make or brand of arsenate of lead	Table	Page	Experimenter	Place	Year	Percentage of—					
						Codling moth (first brood)		Codling moth (late brood)		Curculio	
						Infestation	Control	Infestation	Control	Infestation	Control
Ansbacher paste	31	485	A. J. G.	Griggsville	1914	11.5	98	36.5	59	33.8	90
Corona dry	1[2]	435	O. S. W.	Neoga	1913	18.0	94				
	2[2]	435	O. S. W.	Neoga	1913	18.0	89				
	6	443	O. S. W.	Neoga	1914	14.7	97	76.0	94		
	7[1]	444	O. S. W.	Neoga	1914	6.0	80				
	19[2]	464	A. J. G.	Griggsville	1913	2.5	84 to 92			67.8	79 to 91
	31	485	A. J. G.	Griggsville	1914	11.5	98	36.5	70	33.8	91
Dow paste	6	443	O. S. W.	Neoga	1914	14.7	100	76.0	95		
	7[1]	444	O. S. W.	Neoga	1914	6.0	58				
	31	485	A. J. G.	Griggsville	1914	11.5	85	36.5	53	33.8	71
Grasselli paste	1[2]	435	O. S. W.	Neoga	1913	18.0	83				
	2[2]	435	O. S. W.	Neoga	1913	18.0	72				
	6	443	O. S. W.	Neoga	1914	14.7	73	76.0	84		
	19[2]	464	A. J. G.	Griggsville	1913	2.5	95			67.8	90
	31	485	A. J. G.	Griggsville	1914	11.5	96	36.5	77	33.8	86
Grasselli dry	6	443	O. S. W.	Neoga	1914	14.7	68	76.0	64		
	7[1]	444	O. S. W.	Neoga	1914	6.0	67				
Hemingway paste	2[2]	435	O. S. W.	Neoga	1913	18.0	61				
Sherwin-Williams paste	1[2]	435	O. S. W.	Neoga	1913	18.0	78				
	6	443	O. S. W.	Neoga	1914	14.7	99	76.0	94		
	7[1]	444	O. S. W.	Neoga	1914	6.0	60				
	31	485	A. J. G.	Griggsville	1914	11.5	76	36.5	2	33.8	64
Sherwin-Williams dry	6	443	O. S. W.	Neoga	1914	14.7	97	76.0	92		
	7[1]	444	O. S. W.	Neoga	1914	6.0	58				
	31	485	A. J. G.	Griggsville	1914	11.5	100	36.5	31	33.8	72
Thomsen triplumbic paste	2[2]	435	O. S. W.	Neoga	1913	18.0	72				
	6	443	O. S. W.	Neoga	1914	14.7	97	76.0	92		
	7[1]	444	O. S. W.	Neoga	1914	6.0	83				
	31	485	A. J. G.	Griggsville	1914	11.5	98	36.5	52	33.8	80
Vreeland dry	2[2]	435	O. S. W.	Neoga	1913	18.0	22				

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[1] Results for second-brood codling moth are not given here, owing to the use of one kind of arsenate of lead only for later sprays.

[2] Results for late brood of codling moth are omitted because no spray was applied for their control.

TABLE 37.—EFFECTS OF CERTAIN NEW AND PROPRIETARY FUNGICIDES, IN FIELD EXPERIMENTS IN SPRAYING, 1913 AND 1914

Table	Page	Experimenter	Place	Year	Fungicide	Percentage of—						Foliage injury
						Scab		Sooty blotch		Russet	Burn	
						Infection	Control	Infection	Control			
4	437	O. S. W.	Neoga	1913	Copper ferrocyanide.........	.00		.0		.00	.00	None
—	445	O. S. W.	Neoga	1914	Copper ferrocyanide.........	.00		.0		.00	.00	
21	466	A. J. G.	Griggsville	1913	Copper ferrocyanide.........	1.41	81	5.0	82	.29	.00	Slight
33	487	A. J. G.	Griggsville	1914	Copper ferrocyanide.........	.00		8.5	100	0 to 1.0	.00	None
—	445	O. S. W.	Neoga	1914	Sherwin-Williams tuber tonic..	Destroyed fruit and foliage						
—	445	O. S. W.	Neoga	1914	Calcium hyposulfite..........	Fruit highly colored						
—	445	O. S. W.	Neoga	1914	Thomsen atomic sulfur.......						10.00	
22	469	A. J. G.	Griggsville	1913	Thomsen atomic sulfur.......	1.41	100	5.0	98	.00	.00	None
32	487	A. J. G.	Griggsville	1914	Thomsen atomic sulfur.......	.00		8.5	100	.25	4.75	Slight
—	445	O. S. W.	Neoga	1914	Grasselli soluble sulfur.......	Caused slight foliage injury						
—	445	O. S. W.	Neoga	1914	Niagara soluble sulfur........	Caused slight foliage injury						
22	469	A. J. G.	Griggsville	1913	Niagara soluble sulfur........	1.41	100	5.0	98	.00	.00	Serious
32	487	A. J. G.	Griggsville	1914	Niagara soluble sulfur........	.00		8.5	100	.00	6.25	Serious
Average all experiments......					Bordeaux..................		100		100	79.5	.00	Medium
Average all experiments......					Lime sulfur		97		100	2.2	3.00	Slight

Thomsen atomic sulfur compared favorably with Bordeaux and lime sulfur as a fungicide; it generally caused no russet, but produced a somewhat higher percentage of burn than lime sulfur. Its effect on the health and vigor of the foliage was equally satisfactory with lime sulfur.

Niagara soluble sulfur, tho causing only slight foliage injury at Neoga, so seriously injured the foliage in the experiments at Griggsville that its use cannot be recommended. Grasselli soluble sulfur, used at Neoga in 1914, caused slight foliage injury, but no information regarding its value as a fungicide was obtained owing to the absence of fungous infection.

Sherwin-Williams tuber tonic destroyed both fruit and foliage and was clearly worthless as a spray for apples.

5. *Does the method of making copper ferrocyanide affect its efficiency as a fungicide or insecticide?*

Experience in the use of copper ferrocyanide in 1911 and 1912 indicated that its fungicidal properties were not sufficiently effective or active to control the common apple diseases. The composition of the compound, the ease with which it is prepared, and its excellent adhesive properties, however, commend it as a spray. It was decided, therefore, to determine whether different methods of preparation would affect its solubility or its fungicidal properties. This work was performed at Griggsville in 1913, with the results reported in Table 21, page 466, and discussed on pages 467 and 468.

Briefly, the tests included the preparation of copper ferrocyanide by mixing the ingredients, copper sulfate and potassium ferrocyanide, in cold-concentrated, hot-concentrated, and cold-dilute solutions. The very light attacks of fungi rendered comparisons of the fungicidal value of copper ferrocyanide prepared by the several methods insignificant; it is believed that the small differences shown in the results are not to be attributed to the sprays but to unequal infections of the diseases in the plats. As an insecticide, copper ferrocyanide without arsenate of lead prepared by all methods proved worthless.

The extremely insoluble character of copper ferrocyanide has been suggested as an explanation for its ineffectiveness as a fungicide and insecticide. An experiment was performed at Griggsville in 1914 in which acetate of lead was added to the copper ferrocyanide as an accelerating solvent, with the results presented in Table 33, page 487, and discussed on page 488.

Owing to the absence of apple scab, no data were obtained bearing on the control of this disease. The data presented indicated that the spray controlled sooty blotch, but the experimenter states that the freedom of the sprayed plats from sooty blotch may have been due to their location on a slightly higher elevation than the check plats rather than to the effects of the spray. Moreover, the addition of the accelerating solvent failed to increase the insecticidal properties of the spray to any practical extent. Except where arsenate of lead was added to the spray, the fruit lacked finish and was in no way superior to unsprayed fruit. The foliage was vigorous, but inferior to that on trees where arsenate of lead was also used.

Tho the results presented in Tables 21, 33, and 37 are not sufficiently decisive to warrant a sweeping condemnation of copper ferrocyanide as a fungicide, no matter how prepared, they certainly show nothing that would warrant its recommendation, while as an insecticide it has little or perhaps no value.

6. *What effects have varying quantities, pressures, and nozzle openings on the effectiveness of the sprays?*

Table 38 presents data on the effects of varying quantities, pressures, and nozzle openings on the control of insects and fungi, and on russet and burn. Large quantities refer to drenching sprays; small quantities to thin but complete coatings of spray corresponding rather closely to ordinary commercial spraying. High pressures were from 190 to 250 pounds, low pressures from 100 to 150 pounds. Large nozzle openings were .07 of an inch in diameter, small nozzle openings, .05 of an inch. The large size was, therefore, approximately twice as large as the small one. The openings were of the same size as the large and small openings ordinarily found in commercial nozzles of the disc type.

Large quantities of spray in nearly all cases gave more protection from insects and diseases than small quantities, but caused spray injury on the fruit. In the control of the late broods of codling moth the results are inconsistent and so low in both cases as to indicate that the spray was not applied at the right time. There are indications that moderate amounts applied so carefully as to coat every leaf and apple will satisfactorily control apple scab and sooty blotch, and at the same time prevent serious spray injury, but that large amounts are more satisfactory for the control of first-brood codling moth, curculio, and apple blotch.

High and low pressures varied less in their effects than did large and small quantities of spray. High pressures clearly controlled first-brood codling moth more effectively than low pressures, but the differences were not so great as might have been expected. In the only report on the control of late broods of codling moth, high and low pressures were equally effective. Practically, they were of equal effectiveness, also, in the control of scab and blotch. With regard to spray injury the results must be interpreted with reference to the quantity factor as well as the pressure factor. The table shows that in one case high pressure caused 8 percent serious russet while low pressure caused none; in another experiment high pressure and low pressure caused equally serious injury, and in a third experiment low pressure caused more injury than high pressure. At Neoga there was

TABLE 38.—EFFECTS OF LARGE AND SMALL AMOUNTS OF SPRAY, HIGH AND LOW PRESSURES, AND LARGE AND SMALL NOZZLE OPENINGS, IN FIELD EXPERIMENTS IN SPRAYING, 1913 AND 1914

Treatment	Table	Page	Experimenter	Place	Year	Percentage control—						Russet (serious)	Burn (serious)
						Codling moth (first brood)	Codling moth (late broods)	Curculio (serious)	Apple scab	Sooty blotch	Blotch		
[1]Large amount	13	455	W. A. R.	Flora	1913				97		82	25.40	0
Small amount	13	455	W. A. R.	Flora	1913				90		44	10.60	
[2]Large amount	14	455	W. A. R.	Flora	1913	87			98		86	27.90	0
Small amount	14	455	W. A. R.	Flora	1913	70			94		67	8.80	
[3]Large amount	23	469	A. J. G.	Griggsville	1913	73	7	42	100	100		68.25	
Small amount	23	469	A. J. G.	Griggsville	1913	28	-63	32	100	100		26.00	
[4]Large amount	23	469	A. J. G.	Griggsville	1913	96	49	41	100	100		.66	
Small amount	23	469	A. J. G.	Griggsville	1913	100	47	60	100	100		.25	
[3]Large amount	27	478	A. J. G.	Griggsville	1914	90	-8	96		100		30.25	0
Small amount	27	478	A. J. G.	Griggsville	1914	88	45	87		100		2.00	
[4]Large amount	27	478	A. J. G.	Griggsville	1914	98	18	95		100		.00	12
Small amount	27	478	A. J. G.	Griggsville	1914	92	39	95		100		.00	4
Large amount	28	482	A. J. G.	Griggsville	1914	78	40	96		100		4.75	0
Small amount	28	482	A. J. G.	Griggsville	1914	71	28	80		100		.00	
[5]High pressure	5	438	O. S. W.	Neoga	1913	89	75					8.00	0
Low pressure	5	438	O. S. W.	Neoga	1913	67	75					.00	
[1]High pressure	11	454	W. A. R.	Flora	1913				97		70	20.70	0
Low pressure	11	454	W. A. R.	Flora	1913				93		70	20.20	
[2]High pressure	12	454	W. A. R.	Flora	1913	84			97		80	13.90	0
Low pressure	12	454	W. A. R.	Flora	1913	74			97		78	21.70	
[1]Large nozzle openings	15	456	W. A. R.	Flora	1913				98		75	24.50	0
Small nozzle openings	15	456	W. A. R.	Flora	1913				93		65	17.00	
[2]Large nozzle openings	16	456	W. A. R.	Flora	1913	87			97		84	8.00	0
Small nozzle openings	16	456	W. A. R.	Flora	1913	74			93		77	28.00	

[1]Ben Davis. [2]Jonathan. [3]Bordeaux. [4]Lime sulfur. [5]Intermediate pressures omitted.

no quantity check on the pressure experiment; at Griggsville there was no pressure check on the quantity experiment; but at Flora, where the series of experiments was especially planned to investigate this question, corresponding quantity and pressure tests were made. The probable explanation for the above results appears, therefore, in the Flora experiments, where the data showed that spray injury varied with the quantity of spray applied and was not directly attributed to the pressure at which it was applied. Confirmation for this conclusion is found in the results of the quantity experiments at Griggsville, where injury to the fruit varied directly with the quantity of spray applied. The results at Neoga, tho they tend to show that high pressure may be a primary cause for russet, more probably indicate that the quantity of spray rather than the pressure was reponsible for the injury, since, under a higher pressure, the application of a relatively larger quantity of spray occurred. It is to be concluded, therefore, that high pressures can be used safely thruout the entire spraying season provided the quantity of spray applied is properly controlled.

7. *Is it advantageous to interchange Bordeaux and lime sulfur in a spray schedule, using Bordeaux for one or more applications and lime sulfur for the remaining applications?*

Experiments conducted in 1911 and 1912 proved that both lime sulfur and Bordeaux have a place in the spray schedule and indicated that while lime sulfur should be used for the two sprays following the fall of the petals in May or the first part of June, Bordeaux should be used in hot weather during the latter part of June and the remainder of the summer. The effects of Bordeaux and lime sulfur for the cluster-bud spray left room for doubt, some experiments indicating that lime sulfur was as effective as Bordeaux, and others showing less favorable results.[1]

Information bearing on this question was obtained in 1913 and 1914, both from direct experiments made at Griggsville and from results obtained in other experiments where the spray schedule happened to permit comparisons. The direct experiments are recorded in Table 18, page 461, and in Table 25, page 476. These results confirm the desirability of using lime sulfur for the two applications following the fall of the petals, and Bordeaux for July sprays, and in addition they indicate that lime sulfur is more satisfactory for the cluster-bud spray than Bordeaux, since it gave equally good control of fungous diseases and caused no russeting of the fruit. Thruout all the experiments burn occurred only where lime sulfur was used during July, and then in hot weather. Russeting invariably followed the use of Bordeaux for the cluster-bud spray in the experiments at Flora and at Griggsville, but was not always observed in the experiments at

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[1] J. C. Blair et al., Ill. Agr. Exp. Sta. Bul. 185, pp. 193-194.

Neoga. In occasional instances russeting resulted from the use of lime sulfur applied after the fall of the petals (Table 34, page 491), but in these cases the amount was small and generally the plats sprayed with lime sulfur alone were entirely free from this form of injury.

It is definitely concluded from these experiments, therefore, that when fungicides are required, lime sulfur should be used for all the early applications, including the cluster-bud spray, the calyx spray, and other sprays applied in May, or during cool weather in June, and that Bordeaux should be used during hot weather in June and at all times later in the summer.

8. *What are the effects of certain special spray practices on the control of codling moth?*

Experiments on the problem of special sprays included the application of drenching sprays and of several applications made in addition to the regular sprays. Drenching sprays were applied in order to observe their efficacy in controlling first-brood codling moth. The other special sprays were applied in order to test their efficacy in controlling late broods of codling moth.

TABLE 39.—EFFECTS OF DRENCHING SPRAYS ON THE CONTROL OF FIRST-BROOD CODLING MOTH, IN FIELD EXPERIMENTS IN SPRAYING, 1913 AND 1914

Table	Page	Experimenter	Place	Year	Treatment	Percentage control of first-brood codling moth
8	446	O. S. W.	Neoga	1914	Drenching spray (Bordeaux nozzle)	98
					Ordinary spray (Average of disc nozzles)	72
23	469	A. J. G.	Griggsville	1913	Drenching spray (Average of heavy applications)	84
					Ordinary spray (Average of light applications)	64
26	478	A. J. G.	Griggsville	1914	Drenching spray (Bordeaux nozzles)	46
					Ordinary spray (Disc nozzles)	95
27	478	A. J. G.	Griggsville	1914	Drenching spray (Average heavy application)	94
					Ordinary spray (Average light application)	90

Table 39 presents the data obtained where drenching sprays were used. In three cases out of four the drenching spray was more efficacious in controlling first-brood codling moth than the ordinary spray, but in the fourth case it was less than half as efficient. The experimenter in charge explains, however, that as this spray was applied with a hand outfit and thru Bordeaux nozzles, it was impossible to keep up a satisfactory pressure, and that consequently the spray failed to reach the calyx cups so well as the other sprays. In the other three experiments the sprays were applied either with a power outfit or thru disc nozzles under satisfactory pressures. It is concluded, therefore, that a rather large amount driven home under considerable pressure is desirable for the calyx spray.

TABLE 40.—EFFECTS OF SPRAYING FOR LATE BROODS OF CODLING MOTH, IN FIELD EXPERIMENTS IN SPRAYING, 1913 AND 1914

Table	Page	Experimenter	Place	Year	Time of application	Percentage control of late broods of codling moth
4	437	O. S. W.	Neoga	1913	July 8–10	17
9	447	O. S. W.	Neoga	1914	July 8–10	0
30	483	A. J. G.	Griggsville	1914	July 8–10	58
9	447	O. S. W.	Neoga	1914	June 14	54
9	447	O. S. W.	Neoga	1914	Sept. 1	42
9	447	O. S. W.	Neoga	1914	June 14, July 8, Sept. 1	91

Table 40 presents the results of sprays applied especially for the control of late broods of codling moth and forms the basis for one of the most important conclusions derived from the experiments performed in 1913 and 1914. The spray applied July 8 to 10 is the regular second-brood codling-moth spray. The sprays made at Neoga in 1914 on June 14 and September 1 were applied because of the prevalence of adult moths and eggs then in the orchard and because of the failure of the early July spray to control the late broods in 1913. The results show that the regular second-brood codling-moth spray was largely ineffective at Neoga in 1913 and entirely so in 1914, while a spray applied about the middle of June reduced late-brood injury by 54 percent, a spray applied September 1 reduced it 42 percent, and sprays applied both the middle of June and on September 1 reduced it 91 percent. At the same time at Griggsville the early July spray reduced injury from late broods of codling moth by 58 percent.

In connection with these data must also be considered the facts that in both 1913 and 1914 a third or partial third brood of codling moth appeared very late in the summer, and that the weather conditions appeared to be very favorable for a rapid reproduction and development of the insect.

It is concluded, therefore, from these experiments in which codling-moth attacks varied in time and severity with the season and locality that (1) in exceptional seasons, a fixed schedule is likely to fail in effective control; and (2) it is possible, by expert observation, to determine the proper time and the probable need for sprays for late broods of codling moth.

9. *Can lime sulfur be diluted sufficiently to prevent burn in hot weather and at the same time retain its fungicidal effectiveness?*

Table 29, page 482, presents the results of an experiment performed at Griggsville in 1914 to answer this question. The results show almost equal amounts of burn where weak and strong solutions were used, together with equal control of sooty blotch, the only disease recorded. These results, however, are not to be considered conclusive, because of the general absence of fungous diseases and also because of the fact that the greatest dilution used was only 1 in 50.

INCIDENTAL OBSERVATIONS

1. At Neoga in 1914 the trees in the sprayed plats were banded with paper or burlap bands designed to act as traps for pupating codling moths. In confirmation of the favorable results which many times in the past have been claimed for this practice, trap-banding was found to be a useful supplement to spraying in controlling codling moth, especially when the pests are numerous.

2. A fixed spray schedule is based on the proposition that spraying is an insurance to be employed annually against certain frequently recurring insects and fungi whose habits are presumably fairly constant and well known. A fixed spray schedule has the advantage of simplicity and can be learned and followed easily by the majority of fruit growers. Experience has shown its practicability and widely satisfactory results. The results of the spraying experiments in 1913 and 1914, however, raise the question of the advisability of adhering to a rigid spray schedule.

A complete and final answer to the question cannot be derived from the results of the experiments in 1913 and 1914 nor from the combined results of all the spraying experiments performed thus far by this and other experiment stations. From the information now available the conclusion appears warranted that a fixed spray schedule must be the backbone of spraying advice, but that variations from this schedule may be determined by painstaking observations made either by growers whose skill, training, judgment, available time, and knowledge of the theory and practice of orchard spraying fit them to observe and interpret their observations correctly, or by their scientifically trained representatives working in the field and laboratory.

Recommendations

The following recommendations, while largely similar to those presented in Bulletin 185, present certain modifications based on the results of the work in 1913 and 1914, including recommendations regarding pressures; a change from Bordeaux to lime sulfur for the cluster-bud spray; the omission of the application within ten days after the calyx spray except in previously neglected orchards and in seasons favorable for apple scab development; the application of a spray commencing three weeks after the calyx spray, approximately just preceding the hatching of the first-brood codling-moth eggs; and the addition of a special apple-blotch spray six to seven weeks after the fall of the petals in localities where blotch is prevalent.

1. *Dormant-tree Spray.*—This spray is used particularly for the control of San Jose scale. It is applied in the fall after the leaves have dropped or in the spring before the buds have opened, preferably at the latter time. Where San Jose scale is present or is known to infest a certain locality, this spray is a necessity, and it is advised as a matter of precaution in all orchards thruout the state.

The dormant-tree spray should be either commercial or homemade lime sulfur. The commercial lime sulfur testing 33° Baumé should be used at the rate of 11 gallons of commercial lime sulfur to 89 gallons of water, or 11 gallons of commercial lime sulfur in 100 gallons of the spray. This is equivalent to 1 gallon of commercial lime sulfur to 8 gallons water. The homemade lime sulfur, made according to the Illinois formula (100 pounds sulfur, 50 pounds lime, 66 gallons water), is used at the rate of 20 gallons of stock solution homemade lime sulfur to 80 gallons of water, or 20 gallons of homemade lime sulfur in 100 gallons of spray.

The dormant-tree spray may be applied at as high a pressure as the machine in use will permit, preferably 175 pounds or more. Satisfactory work, however, can be done at low pressures if pains are taken to spray thoroly.

2. *First Regular Summer Spray (Cluster-bud Spray).*—This spray is used particularly for the control of apple scab. A secondary object in its use, however, is to kill the various leaf-eating insects which appear early in the season, including bud moth, tent caterpillar, and cankerworm. These insects, tho not always present in large numbers, are likely to cause serious damage and hence must be guarded against. Thruout the southern third of the state this spray may be omitted in orchards which are free from cankerworm, and which were free from serious scab infection during the preceding season.

The first summer application is made after the cluster buds open, as soon as the individual flower buds spread apart, but before the flower buds themselves open. In large commercial orchards it will be found necessary to begin spraying before all the individual flower buds have spread apart, in order to complete spraying before the first blossoms open. Spraying may be continued at this time until the petals have commenced to separate, but should be discontinued as soon as the stamens and pistils of the flowers are exposed.

Lime sulfur at the rate of 2½ gallons of commercial concentrated, or 5 gallons of homemade (Illinois formula) solution in 100 gallons of spray, with 4 pounds paste or 2 pounds dry arsenate of lead, should be used at this application.

This spray may be applied with satisfactory results at all pressures from 100 to 250 pounds. Care must be taken, however, to spray thoroly at the low pressures and to avoid excessive spraying at the high pressures.

3. *Second Regular Summer Spray (Calyx Spray)*.—This spray is used particularly for the control of codling moth, but it is of almost equal importance as a preventive of apple scab. Incidentally, it is advantageous as a protection against curculio and various leaf-eating insects.

It is applied immediately after the fall of the petals, while the lobes of the calyx are still distended. The greater number of the first-brood codling moth enter the apple thru the calyx end. By spraying the trees while the calyx cups are still open, poison will be placed on the bases of the lobes and stamens and sometimes within the cup itself, where the larvæ of the codling moth are reasonably sure to get it when entering the apple. At this stage the small apples point upward or outward, and the calyxes are easily coated with poison.

For this application lime sulfur arsenate of lead, at the rate of 2½ gallons of commercial concentrated lime sulfur or 5 gallons of homemade lime sulfur (Illinois formula) with 4 pounds paste or 2 pounds dry arsenate of lead in 100 gallons of spray, should be used. This spray is most effective applied at high pressures, but will give good results at all pressures from 100 to 250 pounds. Very thoro work, even at the risk of wasting some material, is advised.

4. *Extra Apple-scab Spray*.—This spray, designed to control apple scab, is necessary in neglected orchards, and is desirable in well-cared-for orchards in cool, showery seasons favorable for the development of apple scab. It should be applied within ten days after the second summer application, or calyx spray. Incidentally it may be helpful in controlling codling moth, leaf-eating insects, and such fungous diseases as blotch, sooty blotch, and leaf spot. These latter, however, are better controlled by the third regular summer spray, which should be applied three weeks after the second, or calyx spray. In the northern part of the state, where the extra apple scab spray is made, the regular third summer spray may be omitted. In the southern

part of the state, however, it is necessary to retain the regular third spray as a protection against apple blotch.

For this application lime sulfur arsenate of lead, 2½ gallons of commercial concentrated lime sulfur or 5 gallons homemade lime sulfur (Illinois formula) with 4 pounds paste or 2 pounds dry arsenate of lead in 100 gallons of spray, should be used. This spray will give good results at all pressures from 100 to 250 pounds.

5. *Third Regular Summer Spray* (*Hatching Spray, First-brood Codling Moth; First Apple-blotch Spray.*)—This spray is designed to supplement the calyx spray in destroying first-brood codling moth. It renews the coating of poison on the exterior of the apple where rapid growth and rains may have thinned it out or removed it, thus insuring a poisoned meal both on the skin of the apple and within the calyx cup when the newly hatched codling moth begins to feed. Usually the application should be made three weeks after the calyx spray in the southern part of the state, and four weeks after the calyx spray in the northern part of the state, but accurate observations of the time of the appearance of the moths and the laying of the eggs may permit an exact determination of the proper time for this spray. This application is the most important one for the control of apple blotch, is often useful in apple-scab control, and incidentally furnishes protection against leaf-eating insects, curculio, sooty blotch, and leaf spot.

For this application lime sulfur arsenate of lead, 2½ gallons of commercial concentrated or 5 gallons homemade lime sulfur (Illinois formula) with 4 pounds paste or 2 pounds dry arsenate of lead in 100 gallons of spray, should be used. This spray will give good results at all pressures from 100 to 250 pounds.

6. *Second Apple-blotch Spray.*—This spray is necessary only in orchards where blotch is prevalent. It should be applied two to three weeks after the third regular summer spray.

Lime sulfur, 2½ gallons of commercial concentrated or 5 gallons homemade lime sulfur (Illinois formula) in 100 gallons of spray, should be used unless the weather is unusually hot (90° F. or above), in which case Bordeaux (8-8-100) should be substituted. Arsenate of lead is usually unnecessary in this spray, but if observations indicate the free hatching of codling-moth larvæ at this time, the poison should be added in the usual proportions.

7. *First Bitter-rot Spray.*—This spray is necessary only in the southern third of the state and in orchards where bitter rot is known to be prevalent. Its application may even be confined, in individual orchards, to localized areas or to susceptible varieties. The time for application is July 1.

Bordeaux (8-8-100) should be used. Pressures from 100 to 250 pounds will give satisfactory results.

8. *Fourth Regular Summer Spray* (*Second-brood Codling-moth Spray*).—This spray is applied particularly for the control of second-brood codling moth. Incidentally it is useful for the prevention of curculio-feeding injury, and, in case a fungicide is added, for blotch, sooty blotch, and leaf spot.

It is made approximately ten weeks after the bloom, or at times varying from July 1 in the extreme southern part of the state to August 1 in the northern part of the state. Exact observations on the time of general emergence of second-brood moths and their period of egg-laying, however, will permit an accurate determination of the time for this spray.

Unless fungous infection is anticipated, 4 pounds of paste or 2 pounds of dry arsenate of lead and 4 pounds of freshly slaked lime in 100 gallons of water should be the spray used. If a fungicide is desired, Bordeaux (8-8-100) should be used. This spray may be satisfactorily applied at all pressures ranging from 100 to 250 pounds.

9. *Extra Bitter-rot Sprays.*—Where bitter rot is anticipated, it is necessary to spray four times at intervals of ten days, commencing July 1. One of these applications, generally the second, will coincide with the regular second-brood codling-moth spray. Following this application, therefore, there should be two extra bitter-rot applications at ten-day intervals.

Bordeaux (8-8-100) should be used at pressures which may vary from 100 to 250 pounds.

10. *Extra Codling-moth Spray for Third Brood.*—Somewhat rarely the apple crop in the southern half of Illinois is very seriously damaged by a third brood of codling-moth larvæ. In such seasons a spray should be applied for their control. The time for the application ought to be determined by careful observations of the appearance of the third brood of adult moths and their period of egg-laying. Such an attack would probably occur between the last week in August and the close of the harvest season. The attack is not likely to come all at once, but will probably be more or less continuous. August 28 to September 3 proved to be the correct time for this spray in the experiments at Neoga in 1914. Observations made at Griggsville during the same season indicated that the second or third week in September would have been the correct time in that locality.

For this spray use 4 pounds paste or 2 pounds dry arsenate of lead and 4 pounds freshly slaked lime in 100 gallons of water. Apply under pressures ranging from 100 to 250 pounds.

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BULLETIN No. 207

WASHING OF SOILS AND METHODS OF PREVENTION

By J. G. MOSIER and A. F. GUSTAFSON

URBANA, ILLINOIS, APRIL, 1918

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WASHING OF SOILS AND METHODS OF PREVENTION

By J. G. MOSIER, Chief in Soil Physics, and
A. F. GUSTAFSON, Assistant Chief in Soil Physics

From careful measurements made of twenty-seven counties in various parts of Illinois, it has been determined that the state consists of approximately two-thirds prairie land and one-third timber land. A considerable proportion of the latter is rolling or hilly, but there is also much timber bottom land and some level timber upland. The total area of the state is 56,650 square miles, or more than 36 million acres. Of this large area, about five and one-half million acres are rolling or hilly and subject to serious erosion. A large part of this land can be cultivated and cropped, but every practical means should be employed to prevent its rapid ruin by erosion.

Some Illinois land has already been completely ruined. Abandoned fields, impoverished by erosion beyond all possibility of reclamation by ordinary methods, are now to be found, especially in the broken and hilly areas of the southern half of the state. In most cases this land should never have been deprived of its protecting forest, the chief thing that made it valuable in the first place.

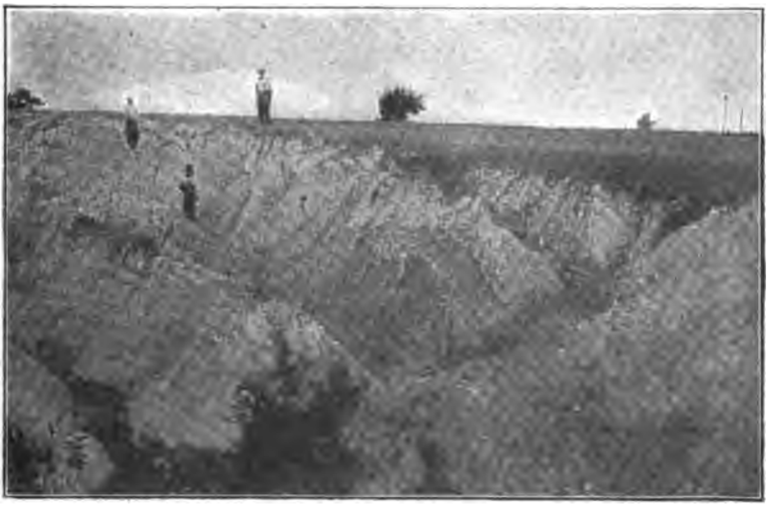

Fig. 1.—Advanced Stage of Erosion in Randolph County

TABLE 1.—APPROXIMATE AREA OF BROKEN AND HILLY LAND IN THE COUNTIES OF ILLINOIS COVERED BY THE SOIL SURVEY PREVIOUS TO 1917

County	Total area of county	Area of broken and hilly land	Percentage of broken and hilly land
	sq. mi.	*sq. mi.*	*percent*
Adams	833.00	233.00	28.00
Alexander	290.00	88.00	30.00
Bond	371.88	74.48	20.01
Boone	288.00	10.00	3.47
Brown	300.00	130.00	43.30
Bureau	877.00	79.80	9.00
Champaign	988.15	3.06	.31
Clay	467.73	69.25	14.85
Clinton	498.00	15.25	2.50
Cook	963.00	11.00	1.14
Crawford	453.00	25.02	5.52
Cumberland	340.43	34.98	10.28
DeKalb	632.70	.43	.07
DeWitt	406.00	19.00	4.75
Douglas	420.00	1.50	.36
DuPage	326.98	7.57	2.32
Edgar	617.27	45.41	7.36
Edwards	218.41	55.71	25.95
Franklin	436.00	30.00	6.88
Grundy	429.00	3.00	.70
Hamilton	438.00	83.00	18.70
Hancock	765.00	200.00	26.14
Hardin	168.00	132.90	79.10
Henderson	374.00	54.00	14.43
Iroquois	1 123.00	2.00	.18
Jackson	558.00	252.00	47.00
Jersey	360.00	151.20	42.00
Jo Daviess	656.00	421.00	64.20
Johnson	336.00	227.07	67.60
Kane	513.14	6.38	1.24
Kankakee	670.13	.92	.14
Knox	720.69	133.71	18.56
Lake	482.82	38.50	7.98
LaSalle	1 156.83	41.12	3.55
Lawrence	362.00	44.25	1.17
Livingston	1 030.00	1.50	.14
McDonough	573.94	144.41	25.16
McHenry	609.52	4.92	.81
McLean	1 168.60	27.43	2.35
Macon	606.00	19.30	3.36
Marion	570.00	46.75	8.20
Mason	553.99	10.01	1.81
Massac	238.00	100.00	42.00
Monroe	385.00	130.00	33.30
Montgomery	702.00	64.00	9.10

TABLE 1.—*Concluded*

County	Total area of county	Area of broken and hilly land	Percentage of broken and hilly land
	sq. mi.	*sq. mi.*	*percent*
Moultrie	341.06	2.19	.64
Ogle	768.00	36.00	4.69
Peoria	620.60	172.59	27.81
Perry	430.00	86.00	20.00
Pike	798.89	381.78	47.79
Richland	360.00	45.75	12.80
Rock Island	441.00	109.00	24.77
Saline	377.56	101.11	26.78
Sangamon	869.48	59.08	6.78
Scott	245.28	51.50	20.99
Shelby	780.00	70.00	9.00
St. Clair	680.00	29.00	19.00
Tazewell	646.91	67.18	10.39
Vermilion	928.00	36.00	4.05
White	512.00	42.00	8.30
Whiteside	700.09	74.24	10.59
Winnebago	515.66	37.17	7.21
Total	35 291.74	5 365.04	
Average for area surveyed			15.20

Besides the broken and hilly land, there is a large area of undulating to rolling land, both timber and prairie, that has not been badly damaged as yet, but which with continued cropping and consequent loss of organic matter is becoming more and more subject to injurious surface erosion. The area of undulating timber soil is approximately the same as that of the hilly land, shown in Table 1.

In the sixty-two counties of Illinois that have been covered by the detailed soil survey, 15.2 percent of the land, as an average, is of such a character that it is subject to serious damage from surface washing. Table 1 gives the area of these counties, together with the area and the percentage of broken and hilly land in each.

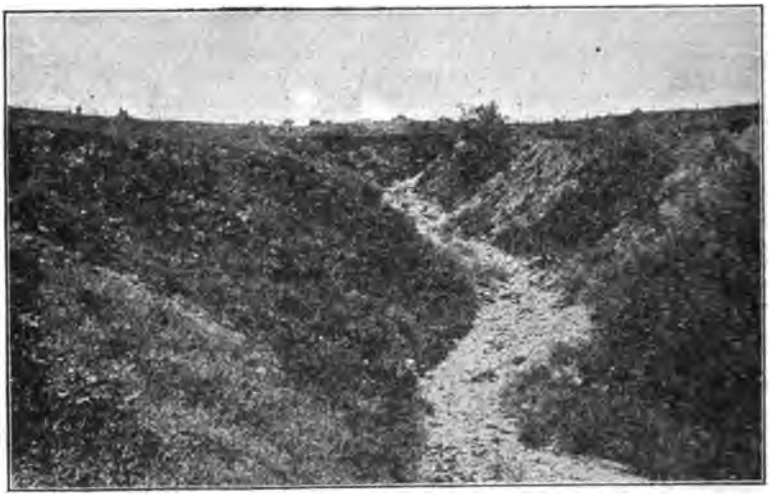

FIG. 2.—A GULLY IN MCHENRY COUNTY

Even gravelly glacial material erodes badly under certain conditions.

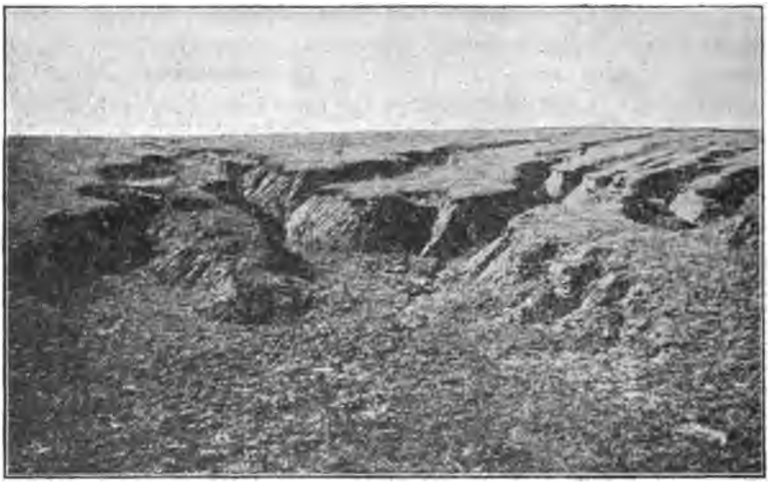

FIG. 3.—EROSION IN OGLE COUNTY

Not a bad slope, but even with the comparatively low rainfall of northern Illinois, considerable damage may be done when gullies are neglected.

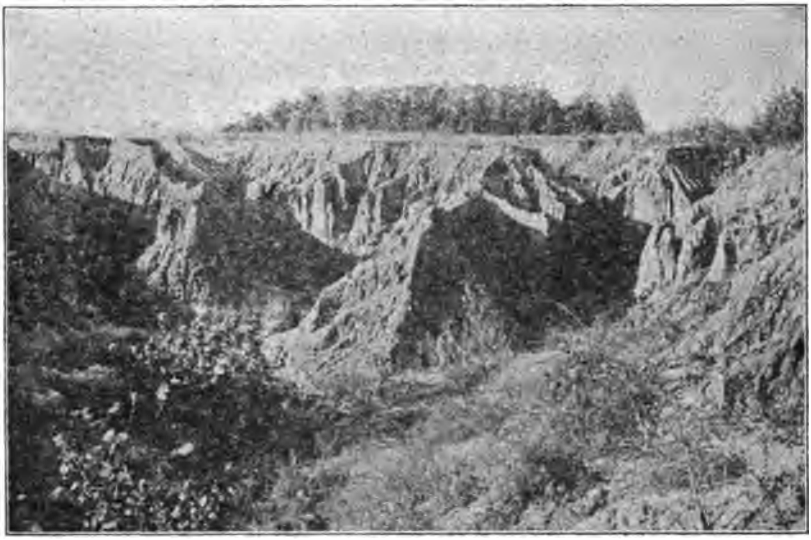

FIG. 4.—ADVANCED STAGE OF EROSION IN ADAMS COUNTY, DUE TO A SUBSTRATUM OF INCOHERENT SAND

RAINFALL IN ILLINOIS

Illinois lies in the belt of prevailing westerly winds. Much of the rainfall comes in moderate or gentle rains, during which a large proportion of the water enters the soil, but in the summer particularly there are very heavy rains, and as the soil is unable to absorb so much water in such a short time, much of it runs off the sloping land. From Table 2, which shows the average rainfall by seasons in the various sections of the state, it will be seen that the greatest rainfall is in the spring and summer months, when the soil is in the best condition to absorb water; but in spite of this fact there is an enormous run-off from the rolling land of the state.

TABLE 2.—AVERAGE SEASONAL RAINFALL IN ILLINOIS

District	Winter		Spring		Summer		Autumn	
	inches	*percent*	*inches*	*percent*	*inches*	*percent*	*inches*	*percent*
Extreme northern[1]	5.44	16.0	9.34	27.4	11.22	33.0	7.99	23.6
Central-northern[2]	5.80	16.8	9.61	27.9	10.75	31.6	8.11	23.7
Central[2]	6.82	18.0	10.43	27.9	11.04	30.7	8.60	23.4
Central-southern[2]	8.80	21.2	11.75	28.3	11.75	28.3	9.18	22.2
Extreme southern[1]	10.66	24.8	12.38	28.5	10.70	24.7	9.54	22.0

[1] 1866 to 1915. [2] 1856 to 1915.

RUN-OFF

The extent to which washing occurs depends upon the amount of surface run-off. The amount of run-off and the effect which it has depends to a large extent upon the character of the soil and subsoil, the length and steepness of the slope, the tillage practiced, and the vegetation growing upon it. Because of these many varying conditions, it is difficult to compute the amount of run-off. Considerable work has been done, however, which may form the basis for a fair estimate. Table 3 gives the results of the work of Mr. F. H. Newell, formerly Chief Hydrographer of the U. S. Geological Survey.

TABLE 3.—PERCENTAGE OF RUN-OFF FROM THE SAVANNAH, CONNECTICUT, AND POTOMAC RIVER BASINS

Basin	Time	Percentage of rainfall carried off in drainage
Savannah river	1884 to 1891	48.9
Connecticut river	13 years	56.5
Potomac river	1886 to 1891	53.0

It has been estimated that for broad valleys and gentle slopes in open country, a mean annual rainfall of 50 inches gives an annual run-off of about 25 inches, or 50 percent of the total rainfall. Where the rainfall is 40 inches, the run-off is about 15 inches, or 37.5 percent; and where the rainfall is 30 inches, the run-off is about 8 inches, or 26.6 percent. Greenleaf estimates the average run-off for the Illinois river basin at about 24 percent of the total rainfall of the catchment area. Leverett estimates the run-off for the entire state of Illinois at about 21 percent of the rainfall.

The work of the Illinois State Geological Survey shows that the run-off for the Spoon river basin is 21.5 percent of the total rainfall; for the Embarrass river basin, 25 percent; and for the Kaskaskia, 37.9 percent. Table 4 will be of interest as showing the run-off in the Kaskaskia river basin for the years 1907 to 1909. The very high run-off in 1908 was due to the extremely heavy rainfall during February, April, and May, when it amounted to 19.57 inches, or more than the total for the rest of the year. The rainfall during May alone was 9.55 inches, or 25 percent of the total for the year.

TABLE 4.—RAINFALL AND RUN-OFF IN THE KASKASKIA RIVER BASIN, 1907-1909

	1907	1908	1909	Average
Rainfall, inches	41.80	38.22	48.48	42.8
Run-off, inches	13.52	19.20	15.07	15.9
Percentage of rainfall lost as run-off	32.34	50.23	31.08	37.9

If the Illinois river basin, with its extensive areas of level to gently rolling land, has a run-off amounting to 24 percent of the annual rainfall, it is certainly conservative to say that the hilly and broken land of the state with perfect surface drainage and slowly pervious soil, suffers at least twice as much loss of water.

WORK OF MOVING WATER

If a current of water with a given velocity is capable of causing a certain amount of erosion, it will be able to do four times as much work if the velocity of the current is doubled. If it is able to carry a certain amount of material at a given velocity, it will be capable of carrying thirty-two times as much with a doubled velocity. If a slowly moving stream carries particles of a certain size, it will carry particles sixty-four times as large when the velocity is twice as great. When a solid is immersed in water it loses weight equal to the weight of the water displaced by it, thus making the material relatively lighter in water than in air, and consequently more easily moved.

Considering the above laws of physics, it will be seen how powerful an agent is moving water for loosening and carrying away soil material.

Since the destructive work of water upon soil depends directly upon the amount and velocity of the water running over the surface, protective and preventive measures should, as a rule, include methods for diminishing the amount and velocity of the run-off.

KINDS OF EROSION

The erosion produced by run-off is of two kinds: (1) sheet erosion, or general surface washing; and (2) gullying, of which there are two phases—head-water erosion and waterfall erosion.

In sheet erosion, the water moves over a uniformly sloping surface, and if the soil and vegetative covering are uniform, the amount of material removed will be practically the same for all points. This form of washing results in the removal of the surface soil and in the gradual reduction of fertility. It occurs to a greater or less extent in practically every field.

Ordinarily, however, the process of washing is not so simple as this. More frequently the slope is not uniform, but contains small draws in which the water collects, giving to the run-off greater velocity and consequently greater erosive power. The water flowing in these draws soon forms a gully. The effect at first is usually greatest toward the lower end of the draw, because of the larger volume of water. Eventually, however, the eroding action of the water increases the steepness of the upper part of the slope, so that even with a smaller volume of water a large amount of work is done, and the gully gradually eats its way up the slope by what is called head-water erosion.

A draw is not always necessary for the beginning of gullies, but there must be something to give direction to the water. On uniform slopes they may be started by very simple agencies. Tunnels made by moles, the tracks of wagon wheels, or paths made by cows, pigs, or sheep may afford the small beginning—and nature will do the rest.

The waterfall type of erosion occurs where the surface material to a depth of two to four feet is more resistant than that beneath. If by any means a waterfall should start, as is often the case where water runs into a ditch or ravine, the undermining action of the water as it falls over the low precipice causes masses of the surface to break off and fall into the gully. This loosened material is carried away and the process repeated. By this means the waterfall slowly moves up the slope, leaving a narrow gully with very steep sides. The waterfall may vary from three to twenty feet in height, but it is usually four to six feet.

These waterfalls are most apt to occur in meadows and pastures where the grass roots make a resistant surface, altho any soil underlain by loose, incoherent material may erode in this way regardless of the method of cropping. The unprotected outlet of a tile ditch may

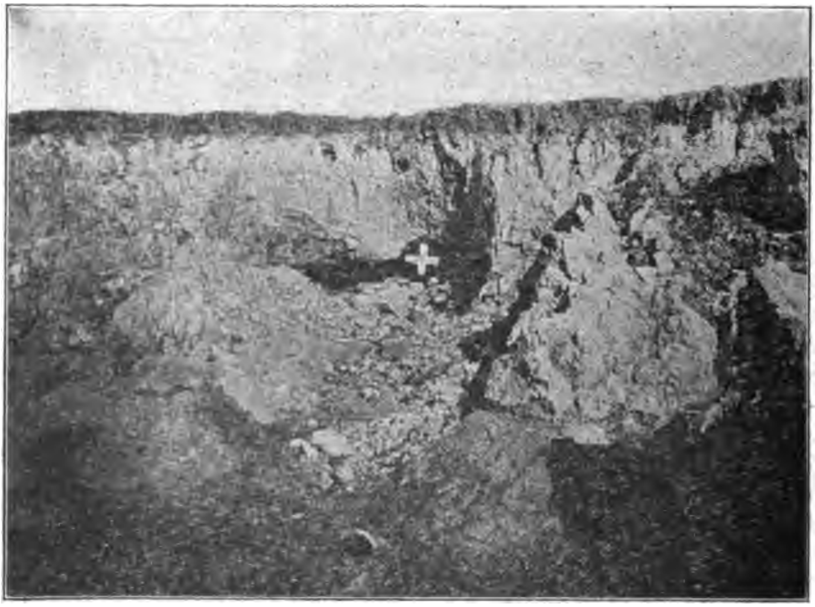

FIG. 5.—HEAD OF GORGE SHOWN IN FIG. 6

Note the condition of the tile outlet. The water undermines the tile by carrying away the incoherent sand at +.

furnish the necessary beginning, especially where the water at the end of the tile has a drop of several feet (see Figs. 5 and 6). Fig. 7 shows a well-protected tile outlet.

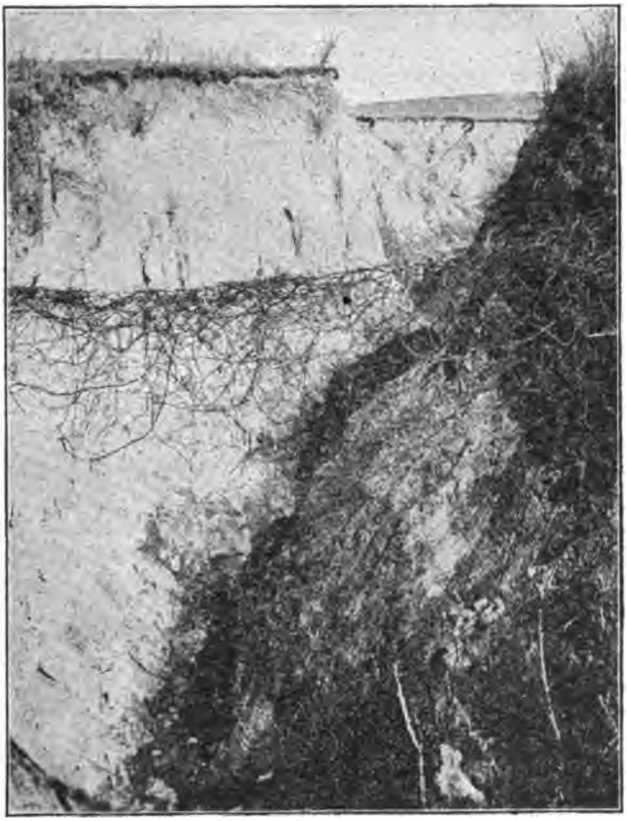

FIG. 6.—A GORGE IN MASON COUNTY

This gorge started about twenty years ago from a neglected tile outlet. The water from the tile washed a ditch, slowly undermined the end of the tile, and backed up about 30 rods, forming a gorge from 40 to 50 feet deep. At the head of this gorge the tile branched, and two gorges started. One of these is now 30 rods long, from 50 to 70 feet wide, and from 25 to 35 feet deep. A concrete dam has been placed near its head to stop further encroachment (Fig. 26). The other gorge has extended about 40 rods and is from 30 to 50 feet wide and from 20 to 30 feet deep. Near the end of this gorge the tile again branches, and two gorges are starting; these have advanced 4 to 6 rods along the tiles. At a depth of 4 to 8 feet there is a stratum of fine, incoherent sand, which washes out very readily, allowing the unsupported surface to cave in (Fig. 5).

EFFECTS OF EROSION

LOSS OF ORGANIC MATTER, NITROGEN, AND PHOSPHORUS

Nothing will completely ruin land more quickly than erosion, especially gullying. A great many fields have already been abandoned from this cause. A single season or even a single rain may produce gullies that cannot be crossed with ordinary farm implements. Unless erosion is practically stopped, the land soon becomes almost worthless (see Fig. 9).

While sheet washing may not ruin land so quickly and so completely as gullying, yet much more damage is done by it because it occurs over a much greater area. This type of erosion takes place to a damaging extent on the undulating land, and to a greater extent upon the more rolling and hilly lands. Prairie soils are not subject to so much erosion as timber soils, since their higher organic-matter content protects them to a considerable degree.

The first effect of erosion is to remove the surface soil. Since this commonly contains a larger supply of organic matter, nitrogen, and phosphorus than any other stratum, its removal naturally lowers the plant-food content in the type of soil most subject to erosion, and increases it in the one receiving the wash.

Hilly timber land is naturally deficient in organic matter, and after it has been cleared and cultivated the run-off soon removes a very large part of the surface soil and along with it the organic matter and the two most important elements of plant food, nitrogen and phosphorus. It should be noted, however, that soils naturally subject to erosion, such as yellow silt loam, may contain as much or even

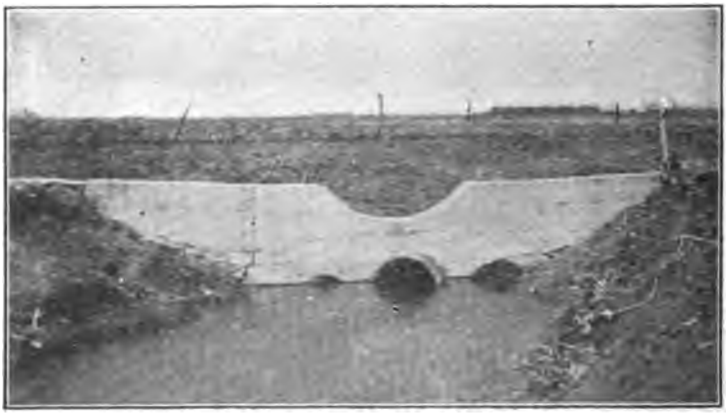

FIG. 7.—A WELL-PROTECTED TILE OUTLET

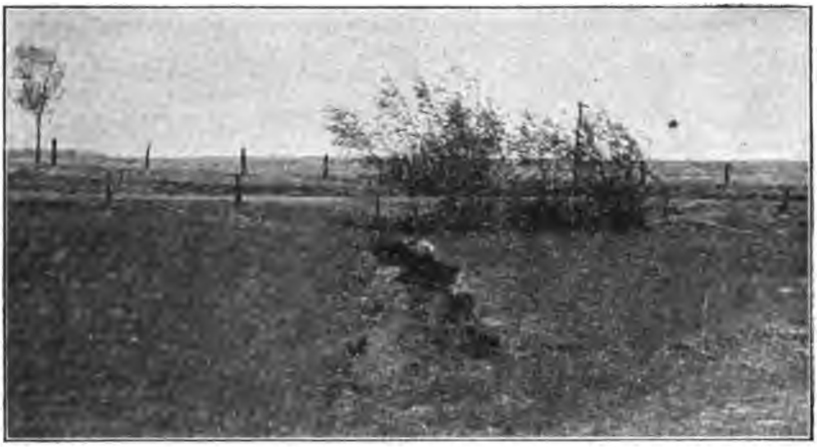

FIG. 8.—WATERFALL EROSION ON PASTURE LAND IN OGLE COUNTY

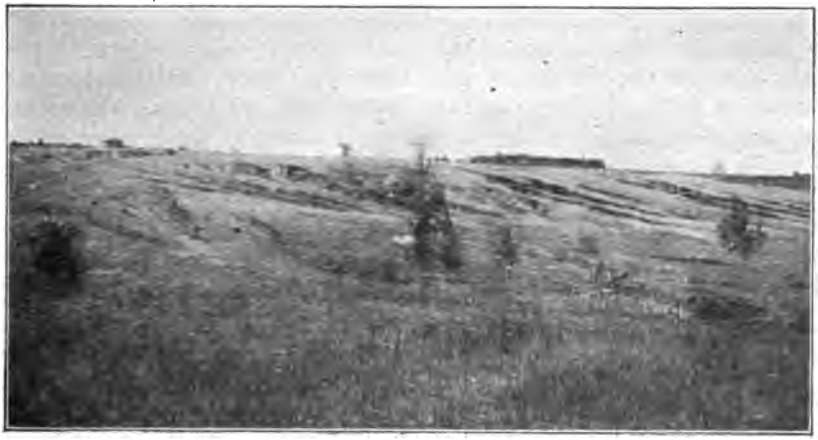

FIG. 9.—EFFECTS OF SHEET WASHING, PIKE COUNTY

more phosphorus in the subsoil or the subsurface than in the surface, even when equal weights are considered.

Table 5 shows the amount of organic matter, nitrogen, and phosphorus in the surface stratum of each of the two representative timber soils in the state and of the bottom land receiving their wash. Yellow-gray silt loam has not suffered much from washing, but yellow silt loam is generally badly eroded. The abandoned land is usually of this latter type. The bottom land receives much sediment from the yellow-gray silt loam areas and some from other less rolling types, but it receives perhaps even more from the yellow silt loam.

TABLE 5.—ORGANIC MATTER, NITROGEN, AND PHOSPHORUS IN THE SURFACE STRATUM OF REPRESENTATIVE TIMBER SOILS AND THE BOTTOM LAND RECEIVING THEIR WASH

2 million pounds of surface soil per acre (0 – 6⅔ inches)

County	Yellow-gray silt loam (undulating)			Yellow silt loam (hilly)			Bottom land (small streams)		
	OM	N	P	OM	N	P	OM	N	P
	tons	*lbs.*	*lbs.*	*tons*	*lbs.*	*lbs.*	*tons*	*lbs.*	*lbs.*
Bond	22.8	2 530	470	19.1	2 068	696	25.4	2 605	1 370
Clay	16.9	1 650	550	14.7	1 540	510	25.1	2 805	1 050
Hardin	13.4	1 520	870	11.0	1 250	840	11.6	1 195	615
Kankakee	26.9	2 710	810	20.7	2 040	720	97.1	9 020	1 560
Knox	22.4	2 440	860	21.9	2 330	820	52.4	4 910	1 790
Lake	27.8	2 720	750	18.1	1 880	720	77.1	8 190	1 490
LaSalle	28.1	2 527	1 033	20.7	2 093	773	36.7	4 440	1 260
McDonough	26.7	2 620	880	18.4	2 140	830	40.5	4 580	1 740
McLean	29.0	2 940	1 050	15.3	1 650	750	62.8	6 300	1 940
Moultrie	24.3	2 310	680	16.6	1 580	480	28.6	3 390	940
Pike	22.6	2 120	780	14.8	1 590	730	34.8	3 230	1 150
Sangamon	22.6	2 300	1 010	8.8	920	820	44.0	4 450	1 630
Tazewell	20.1	2 020	850	15.3	1 710	840	35.9	3 820	1 255
Winnebago	19.6	2 200	870	24.8	2 480	910	63.1	6 770	1 860
Average	23.1	2 330	819	17.1	1 805	746	45.3	4 693	1 403

This table shows that in the surface 6⅔ inches yellow-gray silt loam contains an average of 23.1 tons of organic matter per acre; yellow silt loam, 17.1 tons; and the bottom land, 45.3 tons. The nitrogen and phosphorus content in the surface soil of these three types varies in this same order, the types containing respectively 2,330, 1,805, and 4,693 pounds of nitrogen; and 819, 746, and 1,403 pounds of phosphorus per acre. A nitrogen content of only 1,805 pounds per

TABLE 6.—ORGANIC MATTER, NITROGEN, AND PHOSPHORUS IN THE SUBSURFACE STRATUM OF REPRESENTATIVE TIMBER SOILS

4 million pounds of subsurface soil per acre (6⅔ – 20 inches)

County	Yellow-gray silt loam (undulating)			Yellow silt loam (hilly)		
	OM	N	P	OM	N	P
	tons	*lbs.*	*lbs.*	*tons*	*lbs.*	*lbs.*
Bond	18.2	2 600	1 340	14.7	2 120	1 270
Clay	11.8	1 520	860	13.6	1 830	790
Hardin	11.7	1 500	1 820	8.2	1 390	1 930
Kankakee	20.7	2 710	1 280	17.4	2 160	1 400
Knox	14.5	2 210	1 420	14.7	1 870	1 610
Lake	22.6	2 630	1 300	20.7	2 720	1 620
LaSalle	20.7	2 280	1 907	15.5	2 280	1 387
McDonough	15.0	2 150	1 420	11.5	1 960	1 700
McLean	19.3	2 710	1 490	13.1	2 020	1 540
Moultrie	15.1	2 040	1 100	14.8	1 720	1 200
Pike	24.5	2 140	1 370	12.6	1 600	1 560
Sangamon	14.5	2 150	1 760	11.5	1 540	1 880
Tazewell	12.9	2 090	1 580	11.7	1 650	1 670
Winnebago	14.0	2 220	1 820	25.9	2 980	2 180
Average	16.8	2 210	1 462	14.7	1 990	1 553

acre is not sufficient to produce profitable crops. If that amount is not a sufficient reserve from which to grow fair and profitable crops, what can be expected from a soil whose nitrogen content has been reduced by washing to one-half the above amount, a condition which is produced when the surface soil is removed by erosion (see Table 6). In comparing the figures in Table 5 and Table 6, it will be well to remember that the subsurface stratum is twice the thickness of the surface layer; so that in the subsurface of yellow silt loam, for example, there are but 995 pounds of nitrogen in a stratum of the same thickness as the surface stratum.

CHANGES IN THE PHYSICAL CHARACTER OF THE SOIL

Two distinct changes in the physical character of the soil are produced by erosion: first, a change in color; and second, a change in the physical composition, or texture.

The surface soil of the rolling timber types has a brownish yellow color, owing to the mixture of organic matter and iron oxid. When erosion takes place, the yellow or reddish yellow subsurface or subsoil is exposed. The effect is to slightly reduce the temperature of the soil, since yellow soils do not absorb heat so readily as the darker colored soils.

The most important change in physical character is that of texture. The surface soil is usually a mealy, friable, silt loam, easy to work. The subsoil is often a somewhat tenacious, yellow clayey silt or silty clay, and when this is exposed by erosion it forms a soil that is very difficult to plow and still more difficult to reduce to a condition of good tilth for a seed bed. The physical condition of this subsoil renders it a slow absorbent of water, so that the run-off is actually increased by erosion.

METHODS OF REDUCING EROSION

It would commonly be taken for granted that the thing of first importance in reducing erosion is the preventing of the formation of gullies in cultivated fields, but this is not the case. The beginning of the trouble is usually due to sheet washing, and as a rule gullying occurs in the later stages of the general process of land ruin. If we can prevent sheet washing, we shall very largely lessen gullying in cultivated fields.

REDUCING SHEET WASHING

Five general methods are employed for the prevention of sheet washing: (1) growing cover crops, in order to decrease the movement of water and soil; (2) increasing the organic-matter content, in order to bind the soil particles together; (3) using methods of tillage which will check the velocity of the run-off and cause greater absorption; (4) tiling in order to increase the porosity of the soil and conduct the water thru safe channels; and (5) constructing terraces and embankments which encourage the absorption of the rainfall or so modify the slope of the land as to conduct the surplus water off at a grade that will cause little or no washing.

1. *Cover Crops.*—In the management of rolling land, a rotation should be adopted that will keep the land in pasture and meadow during a large part of the time, or that will at least keep a covering of vegetation on the soil as much of the time as possible. Before these rolling and hilly lands were brought under cultivation, they were largely covered with vegetation of some form. The leaves of trees and fallen branches, together with the smaller plants, formed a covering that did much to prevent the soil from washing. The rainfall was held by the layer of leaves and mold, and the water was allowed to pass off slowly to the streams. But as soon as the protecting forest was removed, the water ran off in a flood almost as soon as it fell. The upland timber soils of the state were usually in poor physical condition when first put under cultivation, or became so after a few years of cropping, and consequently percolation is comparatively slow.

If a cultivated crop is grown, such as corn, a cover crop should be put in just before or after the last cultivation, to protect the soil from washing during the fall, winter, and spring. Rye is one of the best cover crops for this purpose because it lives thru the winter and makes a fair growth of top and an abundance of fine, fibrous roots that hold the soil particles in place. It may be left for green manure or pasture in the spring. A mixture of rye and sweet clover may prove better than rye alone.

Cowpeas may be used as a cover crop with fair success, especially in the southern part of the state, but they do not have the binding power of rye and are killed by frost. The clovers, either sweet, red, or alsike, may make sufficient growth during favorable seasons to protect the soil during the winter and spring, but they are not so sure as rye unless the soil is treated or especially adapted to them. Besides, much of this rolling land in southern Illinois is sour and must be sweetened with ground limestone before clover will do its best.

As already stated, these legumes, aside from their value as cover crops, are also very beneficial to the soil for the nitrogen they supply. The clover may be left and turned under as a green manure in time to plant another crop, such as corn, or it may be harvested or pastured, or, what is better still from the standpoint of soil improvement, the entire crop may be turned under. It must always be borne in mind, however, that a large growth of clover removes a very large amount of moisture from the soil, and when turned under as green manure in dry seasons it may leave the soil so dry that the succeeding crop will suffer.

In general, any crop may be grown as a cover crop that will furnish sufficient material both of top and roots to hold the soil in place. The seeding of rye and timothy in the fall, with red clover and alsike in the spring, followed by pasturing, is one of the very best methods of treatment. Crab grass in corn may make a good cover also.

Much of the rolling and hilly land of the state should be kept in permanent blue-grass pasture (see Fig. 10). If sweet, alsike, or white clover can be grown along with the blue grass, much better results will be obtained. The binding power of blue-grass roots is very great, and gullying is almost entirely prevented except when waterfalls start

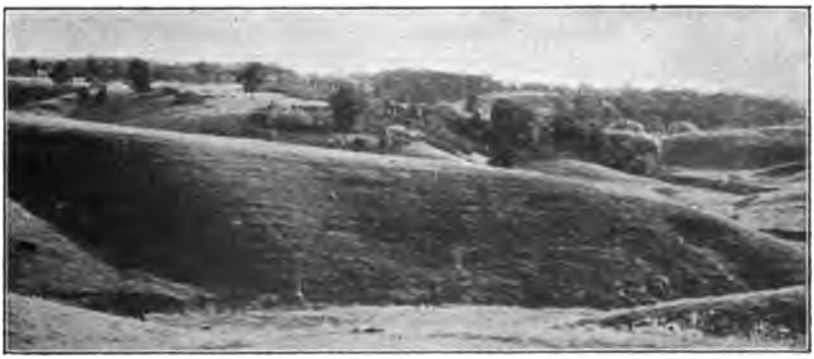

FIG. 10.—A GOOD WAY TO MANAGE HILLY LAND IS TO KEEP IT IN PERMANENT BLUE-GRASS PASTURE

(see Fig. 8) and gullies advance by head-water erosion. If blue grass only is grown, the soil becomes very compact, so that comparatively little rainfall will be absorbed. At most, the amount absorbed is small. Clovers, and particularly sweet clover, with its deep roots, loosen the soil, keeping it in good condition. Besides, the clovers furnish nitrogen for the grass.

2. *Increasing the Organic-Matter Content.*—In the management of the soils of rolling land, it is important to add organic matter, not only because of the effect it has in preventing washing and in producing good tilth, but also because it increases the moisture capacity, conserves the moisture, aids ventilation, and furnishes a supply of nitrogen for the plant (see Fig. 11). One of the effects of organic matter on a soil is to keep it loose and porous by forming granules. In this condition the soil will readily absorb water and the run-off will be greatly reduced. A granular soil will not erode to any considerable extent, not only because there is less run-off, but also because the granules are too large to be moved readily by water. The organic matter also prevents to a large extent the formation of impervious crusts by beating rains.

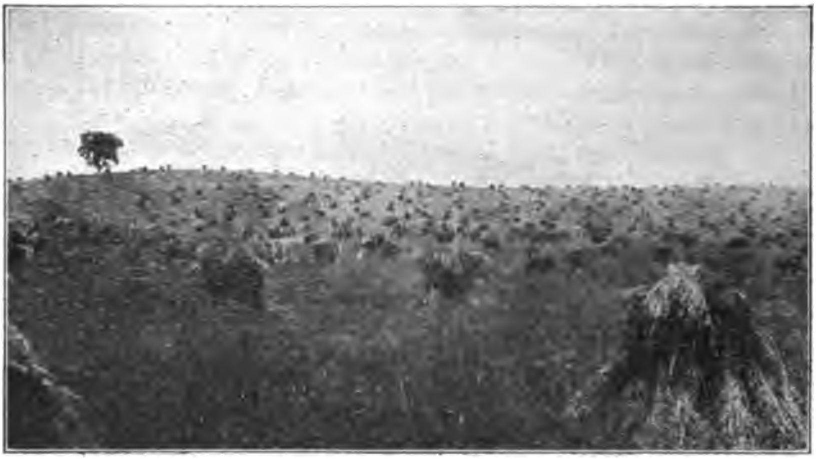

FIG. 11.—WHEAT AFTER CLOVER

Farm of A. P. Schroeder, Pulaski county. Showing possibilities of production on rolling land.

The amount of organic matter naturally present in the soil varies quite widely with the type of soil. In general, the upland timber soils of the state have much less organic matter than the prairie types. The chief reason for this is the fact that in the prairie soils the roots of the grasses which once covered them, being protected by the moist soil, underwent only partial decay, while in the forest the leaves of the trees falling upon the surface of the ground were exposed to complete decay or to destruction by forest fires. Table 7 gives the amount of organic matter in the surface and subsurface strata of the principal types of timber and prairie soils of the state at the present time, calculated from the total amount of organic carbon found.

TABLE 7.—AMOUNT OF ORGANIC MATTER IN THE PRINCIPAL TIMBER AND PRAIRIE SOILS OF ILLINOIS
(Surface 2 million pounds, subsurface 4 million pounds per acre)

Area and county	Timber		Prairie	
	Surface	Subsurface	Surface	Subsurface
	tons	*tons*	*tons*	*tons*
Unglaciated:				
Hardin	12.6	10.4	....	....
Johnson	17.1	13.1	....	....
Average	14.8	11.8	....	....
Lower Illinoisan:				
Bond	19.9	12.4	26.0	26.6
Clay	15.4	10.9	22.9	29.8
Average	17.6	11.6	24.5	28.2
Middle Illinoisan:				
Sangamon	15.7	16.8	44.0	52.2
Upper Illinoisan:				
Knox	22.3	15.5	58.1	66 0
McDonough	27.2	11.7	50.0	59.2
Pike	18.9	17.9	31.5	46.2
Average	22.8	15.0	46.5	57.1
Early Wisconsin:				
LaSalle	24.4	18.0	52.0	47.7
McLean	22.2	17.1	50.7	54.6
Moultrie	19.3	14.8	50.9	48.4
Tazewell	17.5	12.1	57.9	62.7
Average	20.8	15.5	52.9	53.4
Late Wisconsin:				
DuPage	22.4	18.7	65.3	47.6
Lake	19.8	17.0	77.5	78.5
Average	21.1	17.8	71.4	63.1

To show the value of legumes on soils subject to erosion, the results obtained in some pot-culture experiments at the University of Illinois are presented. A soil taken from the washed hill land in Pulaski county was placed in pots, and different elements of plant food were added to all except one pot, which served as a check. Fig. 12 shows the difference in growth due to the different methods of treatment. Wheat was grown the first four years, after which wheat and oats were grown in alternate years. In Pots A2, A11, and A12, after

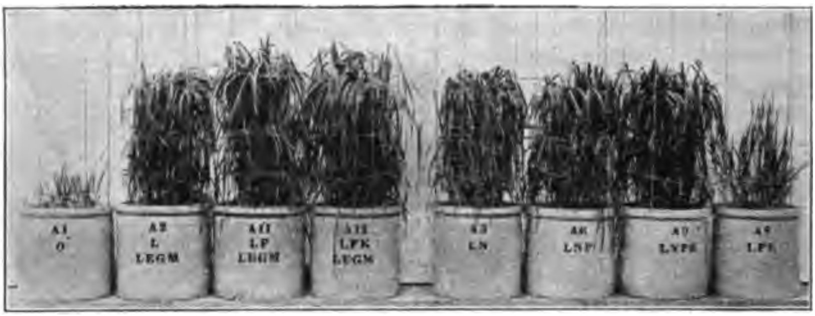

FIG. 12.—EFFECT OF NITROGEN AS SUPPLIED BY LEGUMES OR IN COMMERCIAL FORM

the wheat and oats had been harvested, cowpeas were seeded and turned under for the crop following. The yields obtained under the various treatments are shown in Table 8.

It must be remembered that these yields were obtained in the greenhouse under conditions much more favorable than are ordinarily found in the field. It is interesting to note that the average yields without treatment were 9.0 bushels of wheat and 41.5 bushels of oats

TABLE 8.—CROP YIELDS IN POT-CULTURE EXPERIMENT WITH YELLOW SILT LOAM OF WORN HILL LAND AND NITROGEN-FIXING GREEN-MANURE CROPS
(Grams per pot)

Pot No.		A1	A2	A11	A12	A3	A6	A9	A8
Treatment		None	LLe	LLeP	LLe PK	LN	LNP	LNPK	LPK
1903	Wheat	5.0	10.0	14.0	16.0	17.0	26.0	31.0	3.0
1904	Wheat	4.0	17.0	19.0	20.0	14.0	20.0	34.0	3.0
1905	Wheat	4.0	26.0	20.0	21.0	15.0	18.0	21.0	5.0
1906	Wheat	4.0	19.0	18.0	19.0	9.0	18.0	20.0	3.0
1907	Oats	6.0	37.0	27.0	30.0	28.0	30.0	26.0	7.0
1908	Wheat	4.0	16.3	10.2	16.0	13.0	3.6	7.7	3.5
1909	Oats	10.2	27.2	24.2	34.6	27.4	66.8	51.8	10.2
1910	Wheat	2.1	15.3	20.0	32.8	21.0	37.4	31.4	4.1
1911	Oats	6.4	11.1	20.6	24.2	32.8	38.4	39.5	6.1
1912	Wheat	0.1	19.3	18.4	25.9	25.9	25.9	23.8	4.1
1913	Oats	6.2	26.2	22.2	24.5	27.6	30.8	21.6	7.0
1914	Wheat	0.3	19.9	15.6	21.6	12.2	13.1	9.7	5.2
1915	Oats	12.7	24.0	25.1	22.9	21.3	16.6	17.3	15.5
1916	Wheat	7.0	14.2	10.2	17.5	13.7	7.2	11.4	4.3
Average of 9 years	Wheat	3.4	17.4	16.2	21.1	15.6	18.8	21.1	3.9
Average of 5 years	Oats	8.3	25.1	23.8	27.2	27.4	36.5	31.2	9.2
Yield Calculated to Acre Basis (Bushels)									
Wheat		9.0	46.4	43.2	56.3	41.6	50.1	56.3	10.4
Oats		41.5	125.5	191.1	136.2	137.1	182.6	156.2	45.8

NOTE.—L=limestone; Le=legume; P=phosphorus; K=potassium (kalium) N=nitrogen.

per acre, and with lime, phosphorus, and potassium added they were 10.4 and 45.8 bushels respectively; that with lime and legumes added, the yields were 46.4 bushels of wheat and 125.5 of oats; while with lime and nitrogen (dried blood), they were 41.6 bushels of wheat and 137.1 bushels of oats; and that the average of all pots receiving nitrogen and other plant food was 49.0 bushels of wheat and 154.8 bushels of oats.

The experiment certainly demonstrates the fact that soils subject to erosion need nitrogen; and one of the great problems of the farmer on this kind of land is not only to maintain but to increase the supply of nitrogen in the soil. The most practical way of doing this on an extensive scale is to add organic matter by turning under legumes and manure, ground limestone being used as needed to correct acidity (see Bulletin 115 of this station).

To increase the organic matter in soils, it is necessary to utilize all the vegetable matter produced. Farm manure should be turned back into the soil as soon as possible. Too often it is left piled up against the barn, where it rots the boards and where much of the most valuable part of it leaches away. Weeds, stubble, and corn stalks should be plowed under instead of being burned, as is so frequently done. Crops of rye, or preferably legumes, should be grown and turned under; they will not only increase the organic-matter content, but at the same time augment the scanty supply of nitrogen in these

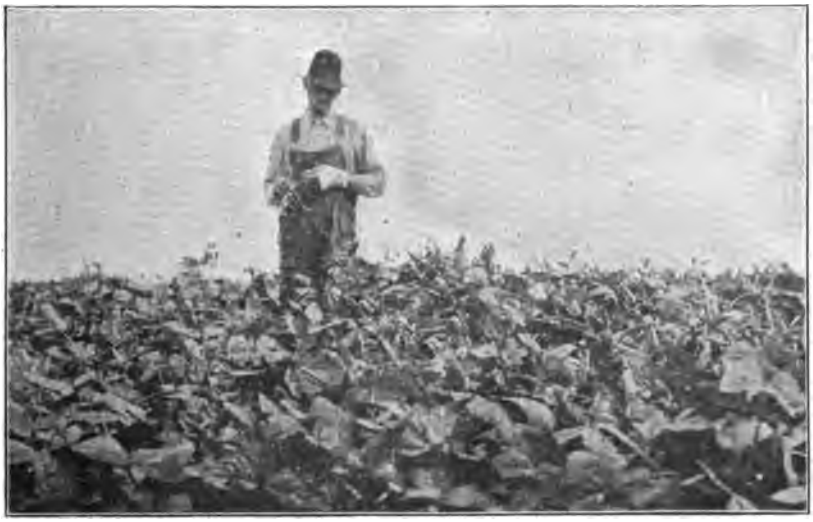

FIG. 13.—COWPEAS ON SERIES C, UNIVERSITY OF ILLINOIS EXPERIMENT FIELD AT VIENNA

When turned under, the cowpeas materially increase the nitrogen and organic-matter content of the soil.

soils (see Fig. 13). A crop of cowpeas or clover is not wasted if plowed under; the increased yield of the succeeding crops may more than pay for it. The turning under of cover crops will help to increase the supply of organic matter, but this is too slow a process on land that is washing badly; one or two entire crops in a four-year rotation should be plowed under until the supply is materially increased.

Sweet clover is one of the best crops to grow for the improvement of eroded land (see Fig. 14) for the following reasons: (1) a surer and better catch may be obtained with it than with red clover; (2) its very deep-rooting nature and large growth makes it most valuable for soil renovation; (3) it will grow on almost any kind of soil, whether badly eroded, good, or stony, the only necessary conditions being the presence of limestone and the proper bacteria; (4) it will furnish a large amount of excellent feed in the form of pasture or hay; (5) it possesses a feeding value as high as that of red clover; (6) it is one of our best honey-producing plants; (7) it will likely be a money crop because of the amount of seed it produces and the price the seed brings.

All forms of organic matter are about equally important to the soil from a physical standpoint, yet legumes are much more valuable than other plants because of the large amount of nitrogen which they contain. A ton of corn stalks contains 16 pounds of nitrogen; oat straw, 12 pounds; wheat straw, 10 pounds; clover, 40 pounds; cowpeas, 43 pounds; and sweet clover, about 40 pounds. A 50-bushel crop

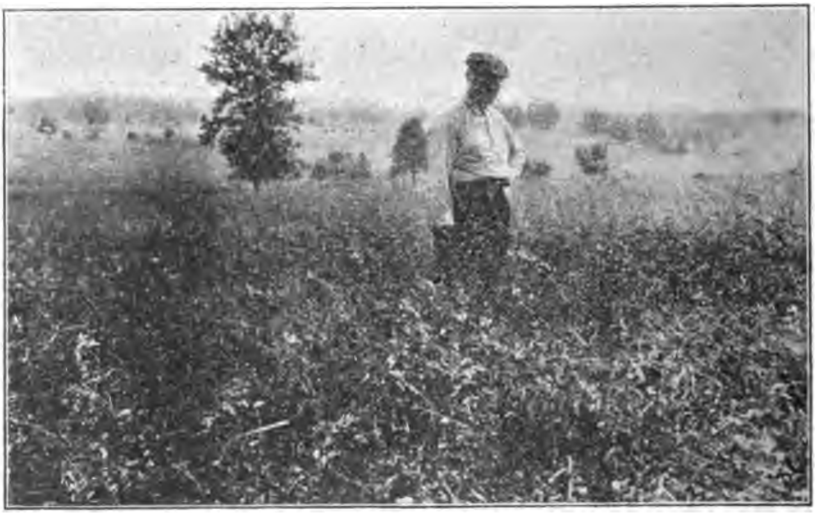

FIG. 14.—SWEET CLOVER ON THE VIENNA EXPERIMENT FIELD

Growth during the first season (seeded in March).

of corn requires for its production 75 pounds of nitrogen. To provide this nitrogen, about 1,500 pounds of average soil humus must be decomposed and lost to the soil. If the average amount of humus in the surface seven inches is 2 percent, or 20 tons per acre, it would require only twenty-seven 50-bushel crops of corn to completely exhaust the supply of soil humus; from which it may be seen that even if a soil has a good store of organic matter to begin with, it does not require a great many years of cropping to reduce the supply below what it should be. This rapid depletion of organic matter is hastened materially by washing, and it soon reduces the soil to a condition of unproductiveness. The more a soil is "run down," the more difficult it is to grow clovers or other soil-renovating crops. (See Bulletin 115.)

3. *Tillage.*—Probably nothing that can be done to rolling land damages it more seriously than faulty methods of tillage. This is a fact which the farmers of Illinois have not yet learned. The direction of plowing, planting, and cultivation is usually determined by convenience alone, regardless of consequences. Plowing is more frequently done up and down the hill than any other way, and the making of dead furrows in this direction affords the best possible beginning for a gully. The work of one season's run-off may be sufficient to produce a gully that the next season's tillage operations will not fill, and the slight draw soon increases and becomes a source of constant trouble.

On land subject to serious washing, plowing should always be done along contour lines, or across slopes, the slopes being kept as uniform as possible in order to prevent any accumulation of water in draws. When done in this way, the water in running across the furrows meets with more obstructions and greater resistance than in running with the furrows, as in up-and-down-hill plowing, and more absorption takes place.

While the direction of plowing is important, the depth is of equal importance, for a deep layer of loose soil will absorb a heavy rainfall without run-off. The soil should be plowed to a depth of six to eight inches.

Planting also should be done across the slope. The authors have observed ditches six inches or more in depth in the track of a planter a week after seeding, where the rows had been run up and down hill. All the corn had been washed out by the water which had accumulated in and followed the planter track. If the corn rows had been run on the contour of the slope, this could not have taken place.

Cultivating up and down the hill allows the accumulation of water between rows, and this results in the formation of a large number of small gullies, in the making of which much soil material is removed (see Fig. 15 and 16). In contour planting, each row retards the movement of water down the slope, thus permitting greater absorption.

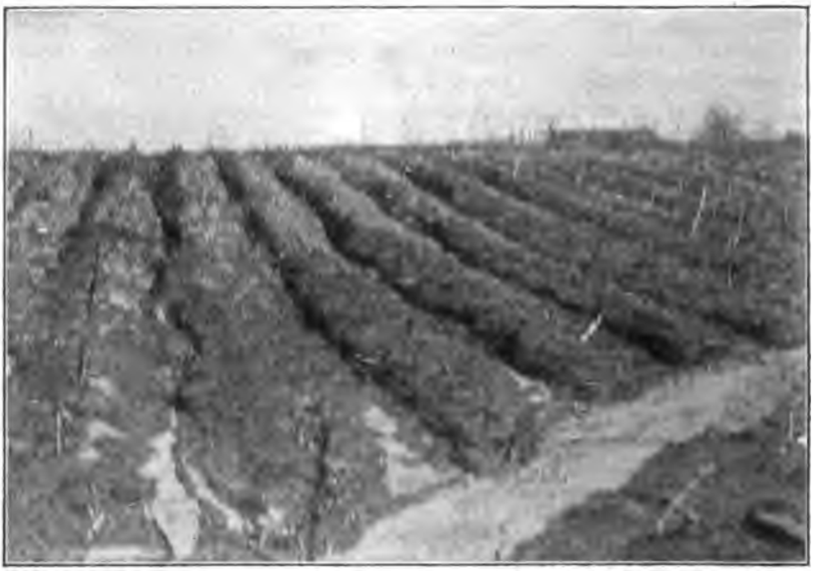

FIG. 15.—GULLIES PRODUCED IN A SINGLE SEASON (1916)

The corn was cultivated up and down the slope.

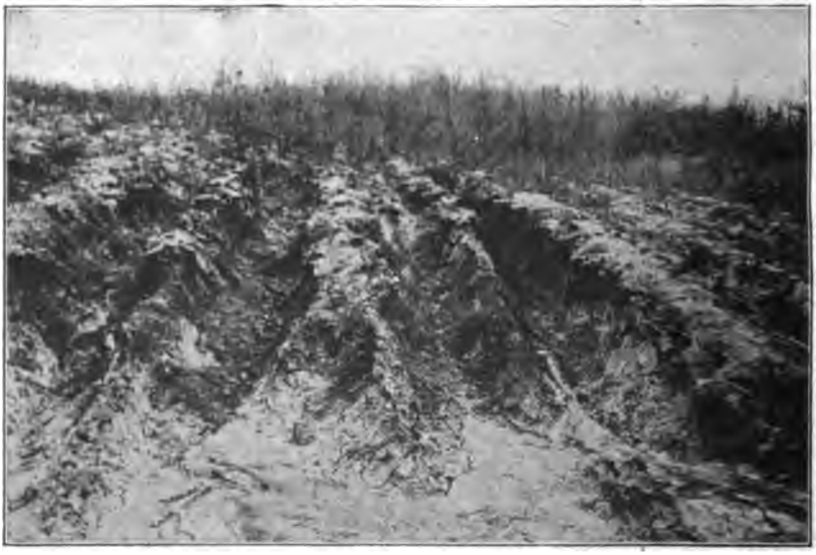

FIG. 16.—ADVANCED STAGE OF GULLYING STARTED IN THE SAME WAY AS IN FIG. 15

Such crops as wheat and cowpeas should also be drilled along contour lines.

4. *Tiling.*—The placing of lines of tile on slopes is a very effective way of reducing erosion. The soil is made more porous, and consequently a large part of the water is removed thru the tile, instead of collecting and running off in draws. Slopes frequently have places where the seepage water comes to the surface, producing cold, wet spots. This condition may be entirely remedied by tiling. The expense involved is the most serious objection to the use of tile in preventing erosion.

5. *Terraces.*—In the southern states it is a common practice to terrace cultivated slopes. The type of terrace depends on the steepness of the slope and the character of the surface soil and the subsoil. The "level bench," "guide row," and "mangum" are all in use.

The level bench is used on the steeper slopes. Contours are established at a difference in elevation of three to five feet. Each terrace is then plowed downward with a hillside plow. In a few years enough soil is moved to make a fairly level bench. Each bench must be cultivated separately, and cuts or tracks across the edge of the bench must be avoided in order to prevent destruction by erosion.

The guide row is developed by throwing several furrows together on contour lines. Crops are seeded along or parallel to these rows. In time, with the use of the hillside plow, these may easily be developed into the level bench. In both of these types there is a strip of uncultivated land on the edge of the terrace. This should have a good sod upon it to hold the soil. This uncultivated strip is undesirable, as it is a waste of land and considerable time is required to keep down the weeds, which aside from their encroachment upon the crop, serve also as a home for mice and moles and as a breeding place for injurious insects.

The mangum terrace (Fig. 17) differs from the terraces just described in that it has some fall from the back to the front of the terrace as well as a grade of about one inch in ten feet from one end of the terrace to the other. The width of the terrace depends on the general slope of the area. In order to build up an embankment, several furrows are thrown together along a line of proper fall established by means of a level, and, to increase its height, soil is drawn to it from the upper side, making a low, broad dyke. When the field is plowed again, the ridge may be raised by back-furrowing along the grade line. This process may be continued from year to year until the desired height is reached. The steeper slopes require a higher embankment. About six feet of fall is allowed between embankments, so that the terraces on very steep land will be 40 to 80 feet wide, and on more gently sloping land 100 to 150 feet wide. By this method the run-off

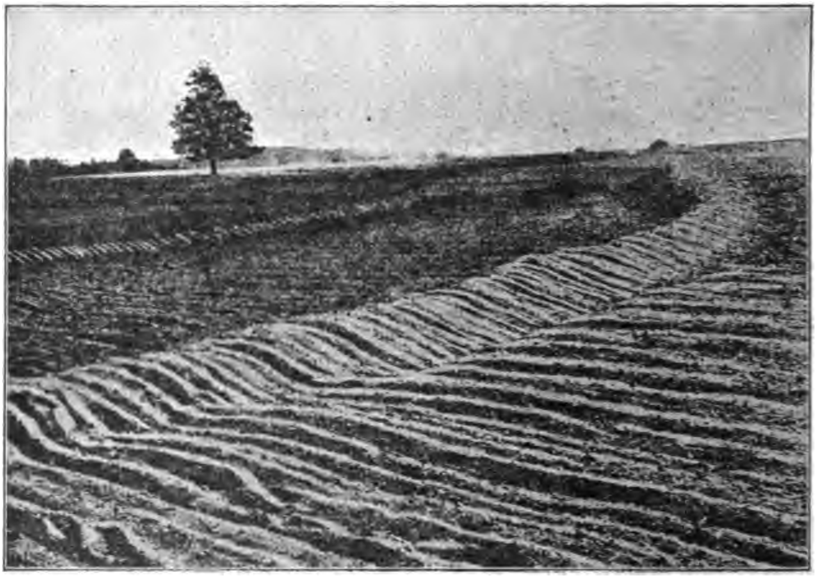

FIG. 17.—MANGUM TERRACE
(Courtesy, Bureau of Plant Industry, U. S. D. A.)

is conducted slowly around the slope in a broad-bottomed ditch to a natural outlet, without much washing. It is essential that the water be given no opportunity to get over the embankment, as it would cut a gully across it, drain the ditch, and ruin this and possibly several embankments below. Crops may be planted in any direction, with little reference to the terraces, but it is most desirable to have the rows run obliquely across them, so that there will be a slight fall along the rows toward the ditch. This should aid the soil in absorbing more of the rainfall. The mangum terrace has a distinct advantage over the other types in that there is no waste land. This form of terrace has attracted much attention, and of the various types, is the one best adapted to extensive farming.

If cover crops and organic matter are used to the best advantage, and if deep contour plowing and contour seeding are practiced, there will not be much need for any terracing in this state. However, the mangum terrace, properly constructed, may in some places be used to advantage.

FILLING AND PREVENTING GULLIES

The owner of rolling or hilly land must be constantly on the lookout for new gullies and must use every means for preventing their enlargement. No attempt should be made to crop the very badly gullied areas. It would be best to reforest these as rapidly as possible.

This will effectually prevent further erosion, and after a few years will be a source of profit as well. Fig. 18 shows a grove of black locust grown on gullied rolling hill land on the farm of J. C. B. Heaton, in Johnson county.

Care must be taken to prevent shallow draws from becoming deep, untillable gullies. A somewhat common method is to scatter straw in them, or to build dams of straw across them at frequent intervals. This is often done in wheat fields after seeding in the fall. Such a method may serve to check the velocity of the water and to catch the sediment, but frequently the run-off is so great that the water washes around the ends of the dams or carries the straw down the draw and deposits it at the base. These dams are sometimes held in place by rows of stakes driven across the draw.

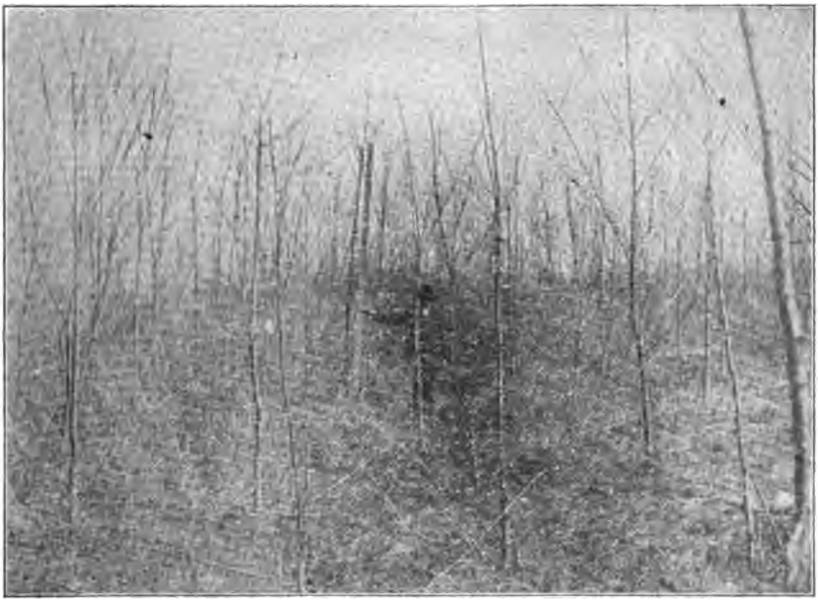

FIG. 18.—BLACK LOCUSTS GROWING ON BADLY ERODED LAND
Farm of J. C. B. Heaton, Johnson county.

A better plan, used a great deal in some parts of the state, is to keep these draws well sodded, at least until they are so well filled that there is little danger of gullies forming (Fig. 19). The sod binds the soil particles together, while the top growth checks the velocity of the water, causing the suspended sediment to be deposited. In time the draw becomes filled so that it may be cropped, but it should be seeded down again if there is danger of a gully forming. Almost any grass

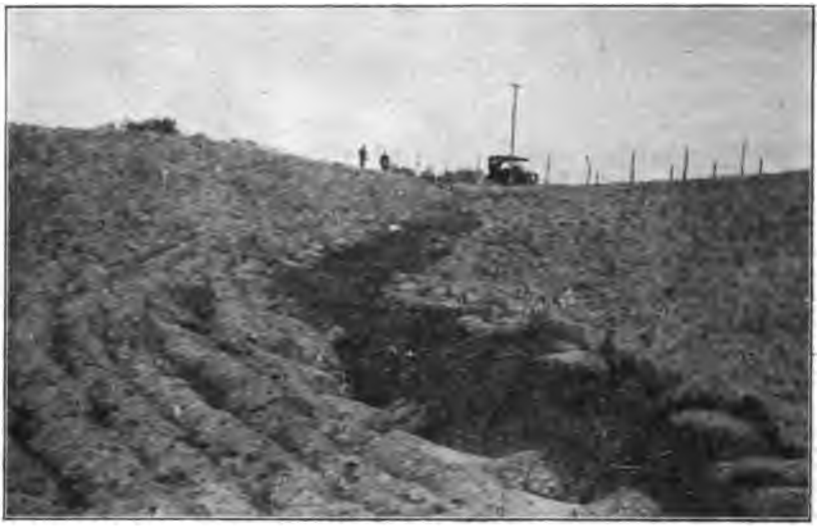

FIG. 19.—SODDED DRAW IN MERCER COUNTY

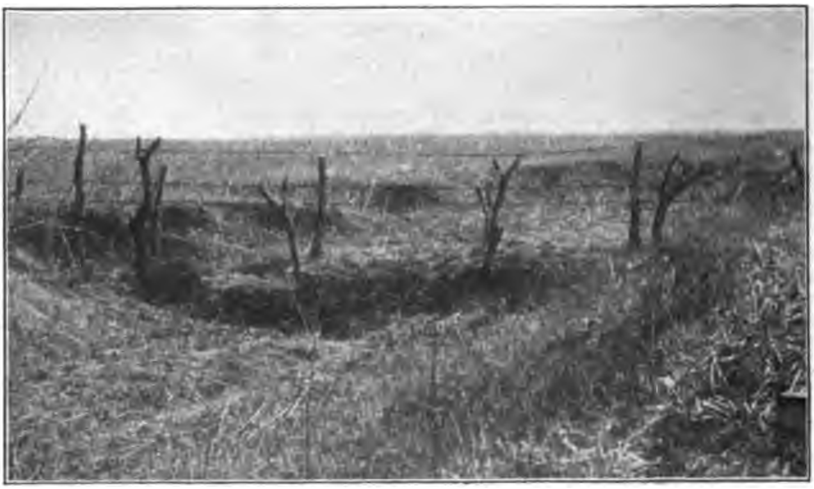

FIG. 20.—DAMS OF STRAW HELD BY WOVEN WIRE FENCING, MASON COUNTY

that forms a tough sod will answer the purpose, timothy, red-top, and blue grass being quite satisfactory. This method is practiced very successfully in some parts of the state.[1] The grass may be mowed for hay.

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[1] Some owners in renting their land insert a clause in the lease forbidding the plowing up of these draws.

Where the gullies are small, the matter of filling them is a simple one, altho care and perseverance are required to keep them filled. If it is desirable to crop the field soon, and the gullies are not too deep, they may be filled with the plow and scraper in a comparatively short time and at little expense. A depression, or draw, must not be left where the gully formerly was, or it will be a constant source of trouble.

Dams of earth, stone, concrete, or straw held by woven wire (Fig. 20) are sometimes constructed across a gully in order to catch the sediment and thus fill the gully and prevent its later formation in the same draw. In many cases this method has been very satisfactory. It may be used for draws as well as for gullies.

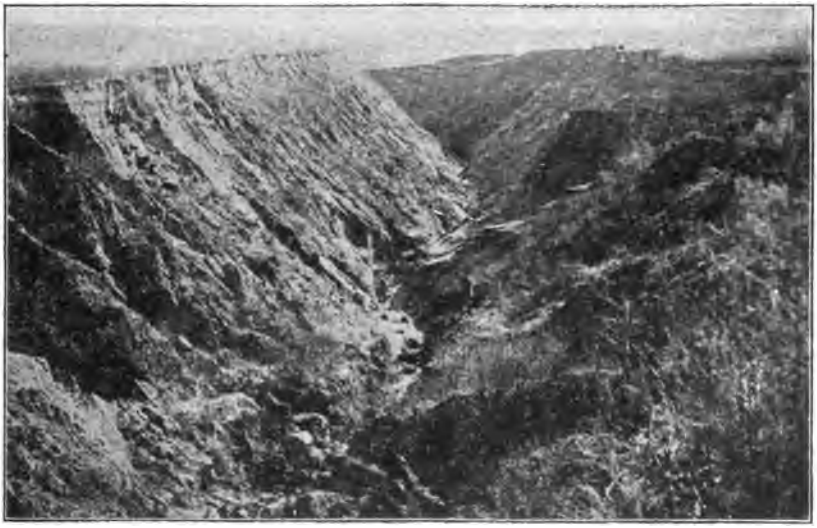

FIG. 21.—A GULLY IN CENTRAL ILLINOIS

This gully started less than forty years ago, and is now from 100 to 150 feet wide and from 25 to 65 feet deep.

The construction of these dams should vary with the size of the gully and the amount of water flowing thru it. If the gully is small, an earth dam constructed as shown in Fig. 22, may be all that is necessary to prevent its enlargement (see Fig. 23). If the gully is large, and the volume of water considerable, a concrete dam should be used which, in addition to the tile, has a spillway over which the excess water may flow. An apron of concrete should be placed under the spillway to prevent the undermining of the dam.

Fig. 24 shows a detailed plan that may be used as a guide in the construction of a concrete dam. The concrete should be well reinforced and anchored on each side. The tile may be placed so as to run either under the dam or thru it. Care must be taken to build the dam with sufficient strength to resist the pressure of the water. The concrete should extend at least two feet below the bed of the stream, or below the frost line. Figs. 25 and 26 show concrete dams in place.

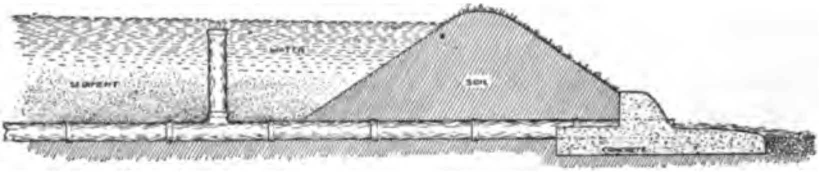

FIG. 22.—DAM OF EARTH

The tile, both vertical and horizontal, must be large enough to allow the water to flow away without any of it going over the dam, as that will ruin it.

The gully produced by a waterfall is one of the hardest to fill, since the fall of the water gives it great eroding power, making it very difficult to stop its undermining action. As such gullies generally occur where the field is in grass, there is a comparatively small amount of sediment carried, and consequently the filling goes on but slowly. The problem is to stop the recession. Straw and brush should be placed under the fall and weighted down with stones or sod, or held in place with stakes to prevent their being washed away. Dams of straw or brush should be placed at intervals below the fall, and even a solid dam of concrete where the gully passes into another field may be of much service in completely filling it in time.

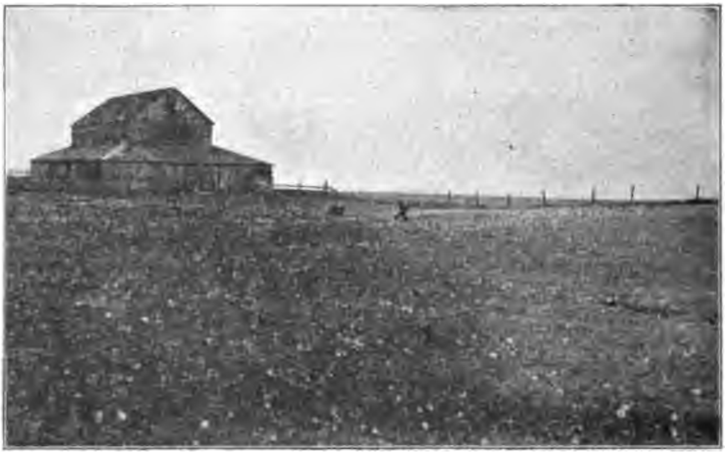

FIG. 23.—DITCH IN CHAMPAIGN COUNTY FILLED BY MEANS OF EARTH DAM

The gully was six feet deep and sufficiently wide at the bottom for a team and wagon to stand crosswise. It was filled in less than ten years.

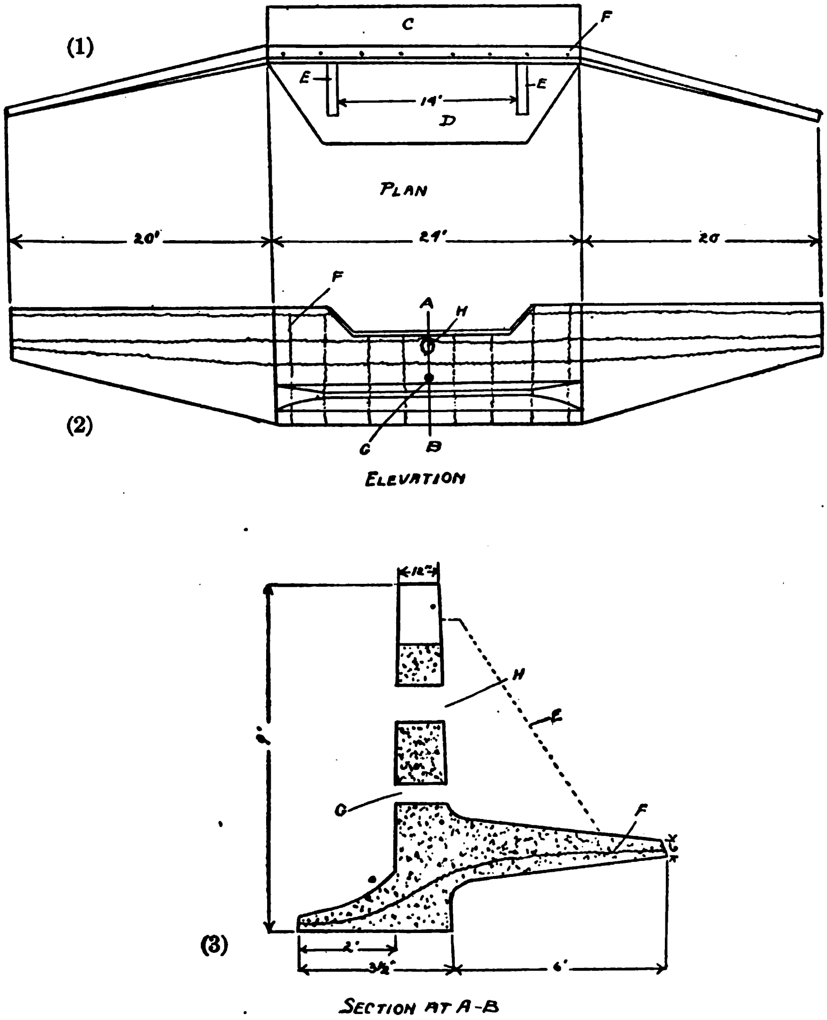

FIG. 24.—DETAILED PLAN FOR A CONCRETE DAM

(1) View from above; (2) Looking upstream; (3) Section. *C*—Upstream apron for preventing underwashing. *D*—Spillway apron of concrete. *E-E*—Concrete abutments for bracing the main dam. *F*—Steel reenforcing rods, horizontal and vertical. *G*—Permanent tile for draining ditch when filled with sediment (the size of the tile will vary with the needs, and may run under the spillway if the ditch is not deep). *H*—An opening may be left in the dam to take care of the water under ordinary conditions and reduce the size of the pond above the dam; this opening should be closed when the ditch is filled with sediment to that level.

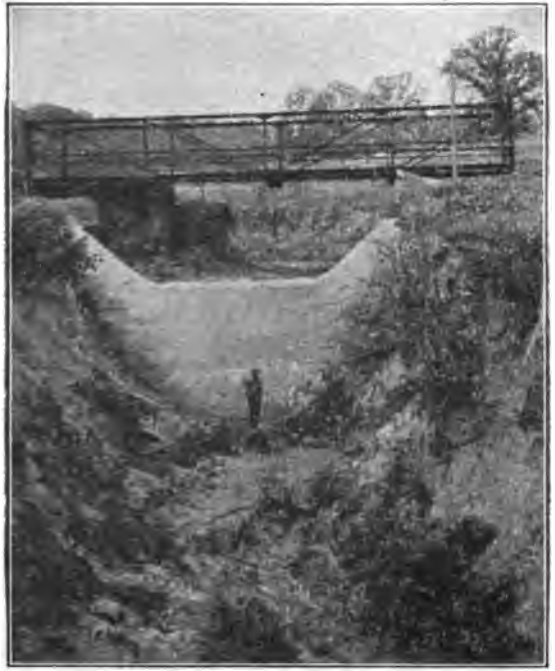

FIG. 25.—FILLING A GULLY BY MEANS OF A CONCRETE DAM

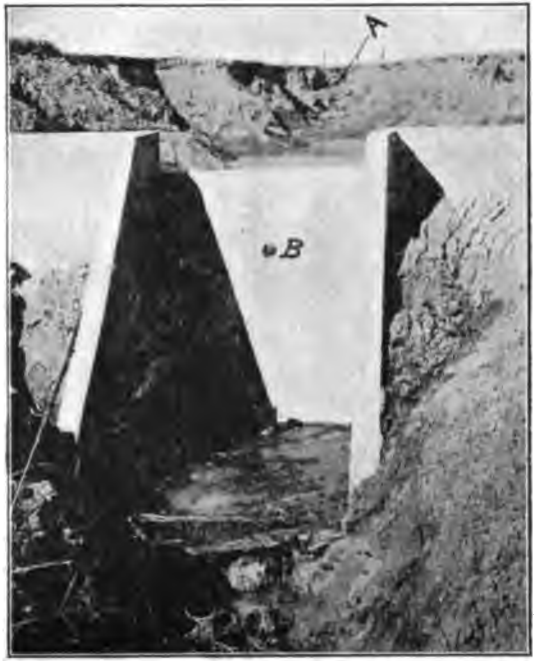

FIG. 26.—A CONCRETE DAM

The gully shown in Fig. 26 is 15 feet deep and 25 feet wide. The dam should have been 4 feet higher, and the tile at *A* connected with that at *B*. During the winter of 1917-18 the water washed around one side of the dam, the wings not extending far enough into the bank of the gully. Note the concrete spillway between the abutments.

RECLAMATION EXPERIMENTS

JOHNSON COUNTY EXPERIMENT FIELD AT VIENNA, ILLINOIS

In the spring of 1906 the Agricultural Experiment Station of the University of Illinois purchased sixteen acres of land in Johnson county near Vienna. The whole area, with the exception of about three acres, had been abandoned because so much of the surface soil had been washed away, and there were so many gullies that further cultivation was unprofitable (Fig. 27). The land was bought for the purpose of reclaiming it and studying different methods of reducing erosion.

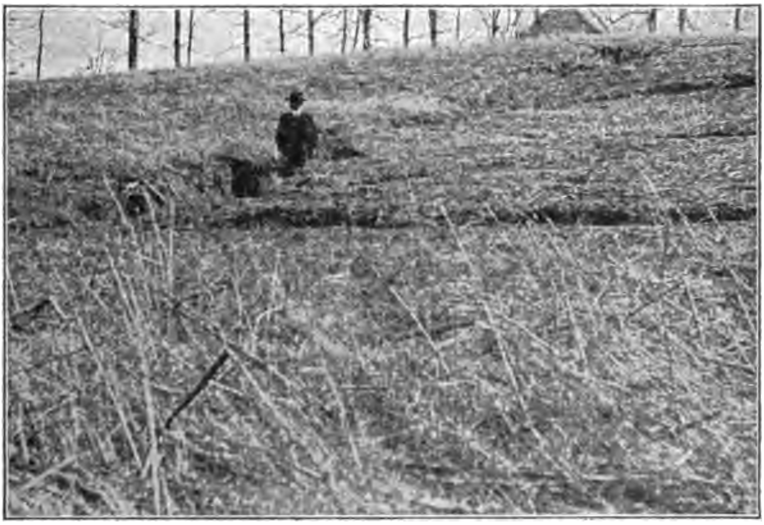

FIG. 27.—VIEW OF LAND IMMEDIATELY ADJOINING THE VIENNA EXPERIMENT FIELD

When the land was purchased, gullying had not gone very far. (See Fig. 28.)

Part of the land was occupied by scrub trees, persimmon, elm, and sassafras, and by blackberry and other brush. This was removed and used in making brush dams in the ditch running north and south across the middle of the field. Some of the gullies were from four to five feet deep, so that the first step in reclaiming the land was to fill them and make the slopes more uniform. This was accomplished with plows and scrapers.

The soil was extremely low in organic matter, the subsoil being exposed on about one-fourth of the field. These conditions were responsible for a large part of the run-off, the low productiveness of the soil, and the injury to crops by drouth. In two places, about a square rod of the underlying rock was exposed.

The field was divided into five series, A, B, C, D, and E, as shown in Fig. 29. The division, it will be noticed by the contour lines, was more or less natural to the lay of the land. Series A, B, C, and D, together with divisions and borders, occupy about thirteen acres, and Series E about three acres. A, B, and C were divided into four plots each; D, into three plots. For each series a somewhat different system of reclamation was planned in order not only to study the problems of reducing erosion, but also to determine which system of reclamation was best under these conditions, as indicated by the crop yields.

Series A includes the steepest part of the area and contained many gullies. These were filled and the area was terraced at vertical intervals of five feet. Near the edge of each terrace, which had a slight slope, a small ditch was placed, so that the water could be carried to a natural outlet at the side of the field without doing much washing. Each terrace was cropped as a separate area.

In two places in Series B were several small gullies, none of which was more than eighteen inches deep. On this series the embankment method was used, except at the steepest part, where two hillside ditches were made for carrying away the run-off.

Series C was washed badly but contained only small gullies. On this series an attempt was made to prevent washing by incorporating organic matter in practicable amounts. In the spring of each year, with the exception of two years, manure at the rate of about eight loads per acre was turned under for corn.

Series D lies just across the hollow from Series C, and was washed to about the same extent. As a check against the various methods for reducing erosion, Series D was farmed in the most convenient way, without any special effort being made to prevent washing.

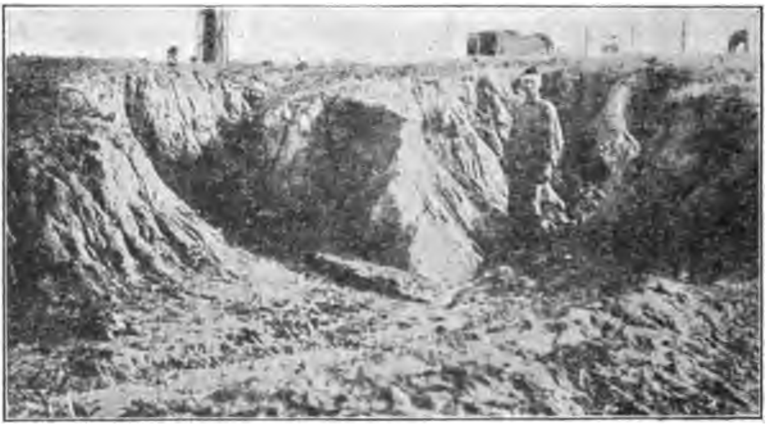

FIG. 28.—SAME AS FIG. 27, BUT TEN YEARS LATER

These series (A, B, C, and D) were not entirely uniform. As already stated, some parts were washed worse than others, and sections of the lower part of the field had been affected by soil material brought from the higher land. When the field was secured, this higher land had a very low productive capacity, as shown by the yield of 9.7 bushels of corn on Series D, and 11.1 bushels on Series C, in 1906, the first year. Many spots would grow little or nothing.

Series E was badly eroded and gullied and was not cropped. An attempt was made to fill the gullies by putting brush into them and seeding to grass, but this was not wholly successful. The area above the gullies was soon covered with vegetation, so that there was little soil material washed into the ditches to aid in filling them. However, the grass and brush prevented the gullies from becoming larger.

Limestone was applied to the entire field at the rate of two tons per acre. No other mineral plant food was applied. Corn, cowpeas, wheat, and clover were grown every year in the order named, as a

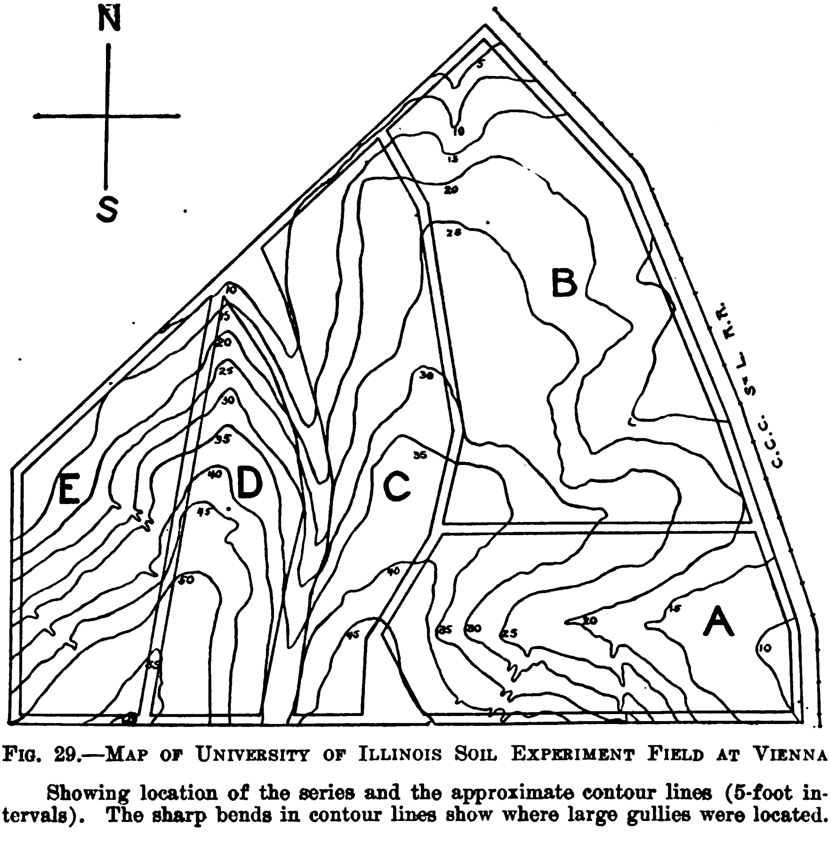

FIG. 29.—MAP OF UNIVERSITY OF ILLINOIS SOIL EXPERIMENT FIELD AT VIENNA

Showing location of the series and the approximate contour lines (5-foot intervals). The sharp bends in contour lines show where large gullies were located.

four-year rotation, together with additional cover crops when necessary. The corn stalks, the second growth of clover, and the cowpeas were turned back into the soil. When clover failed, soybeans were substituted, but these did not make a large growth (seldom more than an ordinary second growth of clover), and were turned under.

Tables 9, 10, and 11 give the yields of the crops by plots on each series.

TABLE 9.—YIELDS OF CORN IN SOIL EXPERIMENTS, VIENNA FIELD: 1906–1915
(Bushels per acre)

Year	Plot	A	B	C	D
1906	1	42.1	18.6	11.1	9.7
1907	4	17.8	24.8	31.0	No plot
1908	3	25.0	44.0	31.5	31.1
1909	2	30.8	41.5	41.2	13.5
1910	1	52.5	36.0	27.7	8.0
1911	4	30.0	31.9	36.5	No plot
1912	3	13.7	37.5	10.8	24.4
1913	2	24.6	36.4	41.8	8.2
1914	1	30.8	13.5	22.6	3.7
1915	4	24.5	14.8	32.1	No plot
Average		29.2	29.9	28.6	14.1

TABLE 10.—YIELDS OF WHEAT IN SOIL EXPERIMENTS, VIENNA FIELD: 1906–1915
(Bushels per acre)

Year	Plot	A	B	C	D
1906[1]	..	....	....	....	....
1907	2	8.9	10.6	9.4	5.6
1908	1	8.9	6.2	8.5	1.5
1909	4	7.3	7.0	12.0	No plot
1910	3	11.5	18.8	16.7	7.8
1911	2	13.1	19.6	20.1	3.7
1912	1	3.0	2.8	0	0
1913	4	6.9	10.0	12.5	No plot
1914	3	9.3	14.7	11.1	8.4
1915	2	8.5	15.3	14.8	5.1
Average		8.6	11.6	11.7	4.6

[1] Oats were sown instead of wheat, but they did not grow high enough to be harvested.

TABLE 11.—YIELDS OF CLOVER IN SOIL EXPERIMENTS, VIENNA FIELD: 1907–1915
(Tons per acre)

Year	Plot	A	B	C	D
1907	3	.75	1.11	.29	.40
1908	2	.20	1.04	.30	.10
1909	1	Clover turned under			
1910	4	.46	1.08	1.20	No plot
1911	3	Failure			
1912	2	Soybeans turned under			
1913	1	1.09	.78	1.81	.14
1914	4	Soybeans turned under			
1915	3	Sweet clover turned under		Soybeans turned under	
Average		.62	1.00	.90	.21

It is difficult to compare the results obtained from the various methods of treatment on the different series because of the variation in the soil, but it can be said that any system that conserves the soil will aid in maintaining the crop yields. Table 12 gives by periods the crop yields obtained under the different methods of management.

TABLE 12.—ANNUAL CROP YIELDS OBTAINED UNDER DIFFERENT METHODS OF MANAGEMENT TO REDUCE EROSION: VIENNA FIELD

Years	Terrace (A)	Embankments and hillside ditches (B)	Organic matter, deep contour plowing, and contour planting (C)	Check (D)
Corn (Bushels per acre)				
1906–08	28.3	29.1	24.5	20.4[1]
1909–11	37.7	36.5	35.1	10.7[1]
1912–15	23.4	25.6	26.8	12.1[2]
Average	29.2	29.9	28.6	14.1
Wheat (Bushels per acre)				
1907–09	8.3	7.9	10.0	3.5[1]
1910–12	9.2	13.7	12.3	5.7[1]
1913–15	7.6	13.3	12.8	6.3
Average	8.6	11.6	11.7	5.3
Clover (Tons per acre)				
1907–8–10–13	.62	1.00	.90	.21

[1] Two-year average. [2] Three-year average.

The average yield of corn for 1912 to 1915 was less than for 1906 to 1908 in every case except where the organic matter was increased. This was due in part to the three dry seasons during the 1912 to 1915 period. Series C and D were on either side of a draw extending north and south, C facing west and D east. Series C received manure in addition to the cowpeas and residues turned under, and every effort was made to prevent washing, tho this was not successful in all cases. Series D, of which no particular care was taken, is now almost worthless because of gullying (Fig. 30). Table 13 gives the average yields for the four series, based on all comparable yields.

TABLE 13.—AVERAGE OF COMPARABLE YIELDS, VIENNA FIELD: 1906–1915

Crops	Years	Series			
		A	B	C	D
Corn (bu. per acre).........	7	31.4	32.4	27.9	14.1
Wheat (bu. per acre)	7	9.0	12.7	11.7	4.6
Clover (tons per acre).......	3	0.68	0.97	0.80	0.21

The average yield of corn for the protected series (A, B, and C) was 30.6 bushels per acre, as against 14.1 bushels for series D; wheat yielded 11.1 bushels in comparison with 4.6 bushels, and clover 0.82 ton in comparison with 0.21 ton.

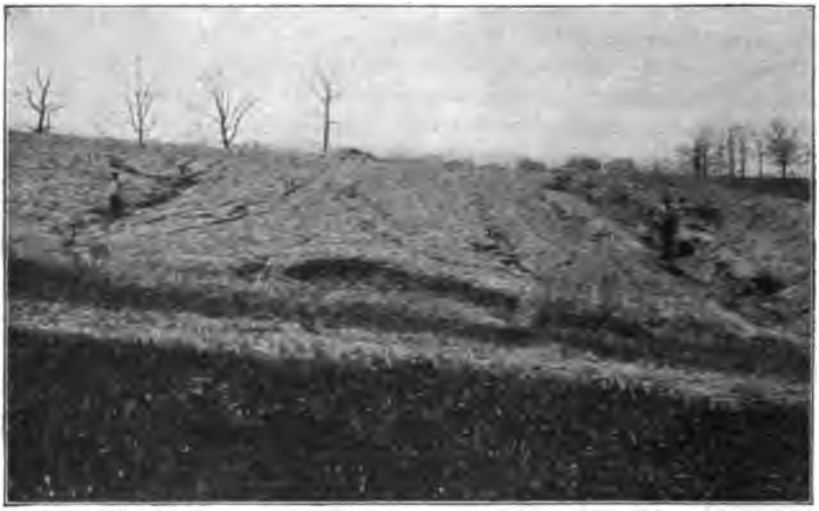

FIG. 30.—VIEW OF PART OF SERIES D, 1916, VIENNA EXPERIMENT FIELD

Note badly eroded condition.

The best biennial legume for soil improvement on eroded land is sweet clover, because as already stated, it catches readily and makes a large growth of both top and root. The second season's growth begins sufficiently early so that if desired a considerable amount may be plowed under for corn the same season (see Fig. 31).

The comparison between Series C and Series D may be somewhat in favor of C since C received some manure. Series A, however, was washed as badly as D in all except the northeast and southeast parts, and aside from terracing received the same treatment as D. The difference in yields here is almost as striking as between C and D. As an average of the comparable yields, A produced 31.4 bushels of corn per acre and D, 14.1 bushels; A produced 9.0 bushels of wheat and D, 4.6 bushels; A produced .68 ton of clover and D, .21 ton. Reclaiming and reducing erosion resulted in an increase of 17.3 bushels of corn per acre, 4.4 bushels of wheat, and .47 ton of clover hay.

Figuring corn at 60 cents and wheat at 80 cents per bushel and clover hay at $7 per ton, the value of the increase due to reclamation and control of erosion for one four-year rotation is $17.19. These three crops represent the total yield per acre, as the cowpeas were turned under. The average annual gain per acre is $4.30; which would mean $172 a year from forty acres, and $1,720 in ten years from forty acres.

The expense of reclaiming the land, which for series A and B consisted in filling gullies and building terraces and embankments, was approximately $18 on 5.8 acres. About two-thirds of this amount was spent on Series A, which had been completely abandoned when the tract was purchased and was badly gullied and more difficult to terrace. Series C and D required but little work, since they contained only a few small gullies and no terracing was done.

The value of the crops removed from Series A during the first rotation was $66.08, or at the rate of $26.43 per acre for four years, or $6.61 per acre per annum. The crops of cowpeas are not included in the above. If $6 per ton is allowed for the cowpea hay, the value of the crops will be increased about $4.50 per acre, making approximately $11.11 per acre on this formerly abandoned land. The approximate cost of maintaining the terraces on Series A was not over fifty cents per acre per annum, and much less on Series B.

This increase in returns pays for all labor of filling gullies and building terraces and maintaining them, and leaves a fair profit on each field where washing is largely prevented and the soil conserved. Series A is in a condition to be cultivated for years to come if properly cared for, while Series D cannot be cropped profitably in its present condition.

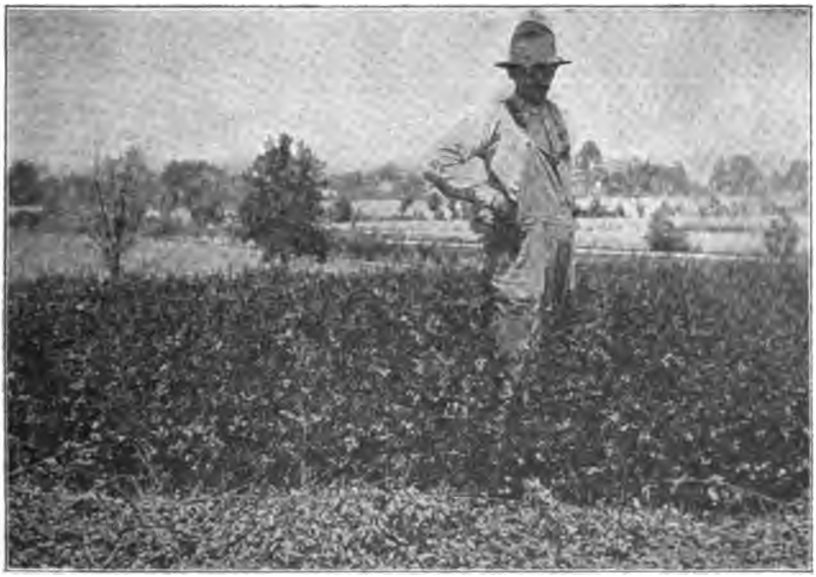

FIG. 31.—SWEET CLOVER ON VIENNA EXPERIMENT FIELD
About 30 inches high, May 31, 1914.

Increasing and maintaining the organic matter, using cover crops, keeping the land in pasture and meadow as much as possible, and practicing deep contour plowing and planting are the most practical means for reducing soil washing in Illinois. If these methods are practiced, much of the badly eroded land can be cultivated with profit.

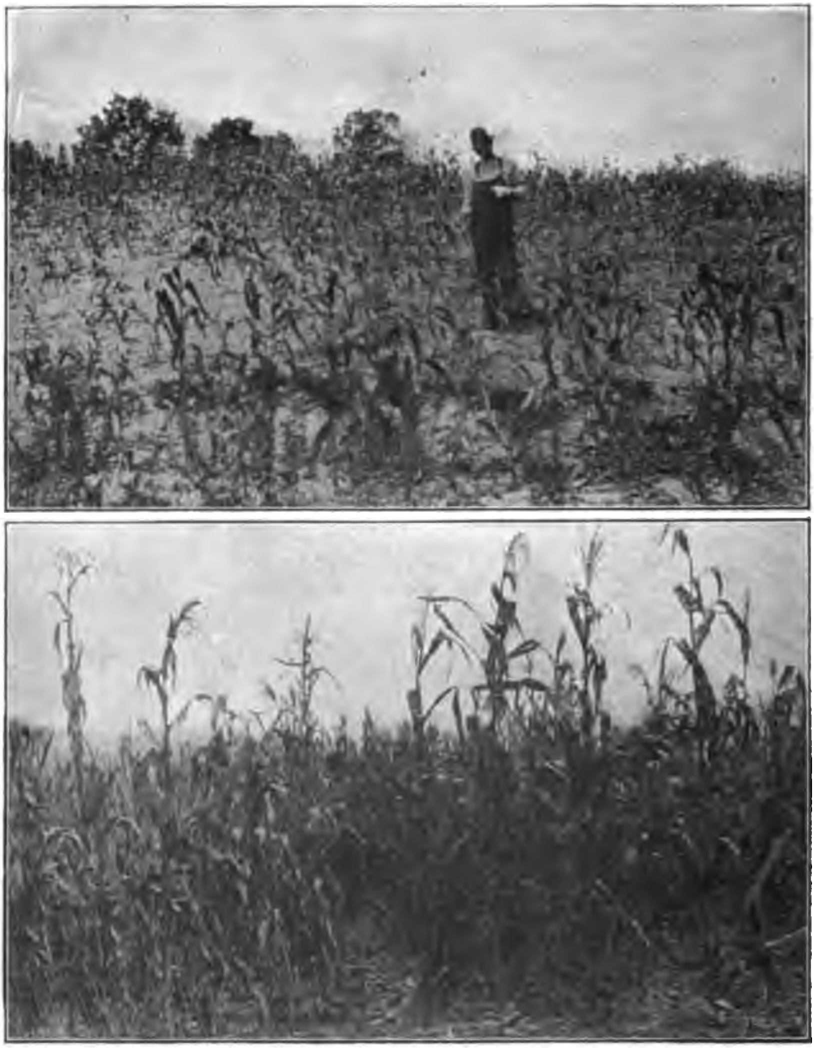

FIG. 32.—CORN ON VIENNA EXPERIMENT FIELD

Upper Section—Series D, 1914; yield 3.7 bushels.
Lower Section—Series C, 1914; yield 22.6 bushels.

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UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

BULLETIN No. 208

CLIMATE OF ILLINOIS

By J. G. MOSIER

URBANA, ILLINOIS, APRIL, 1918

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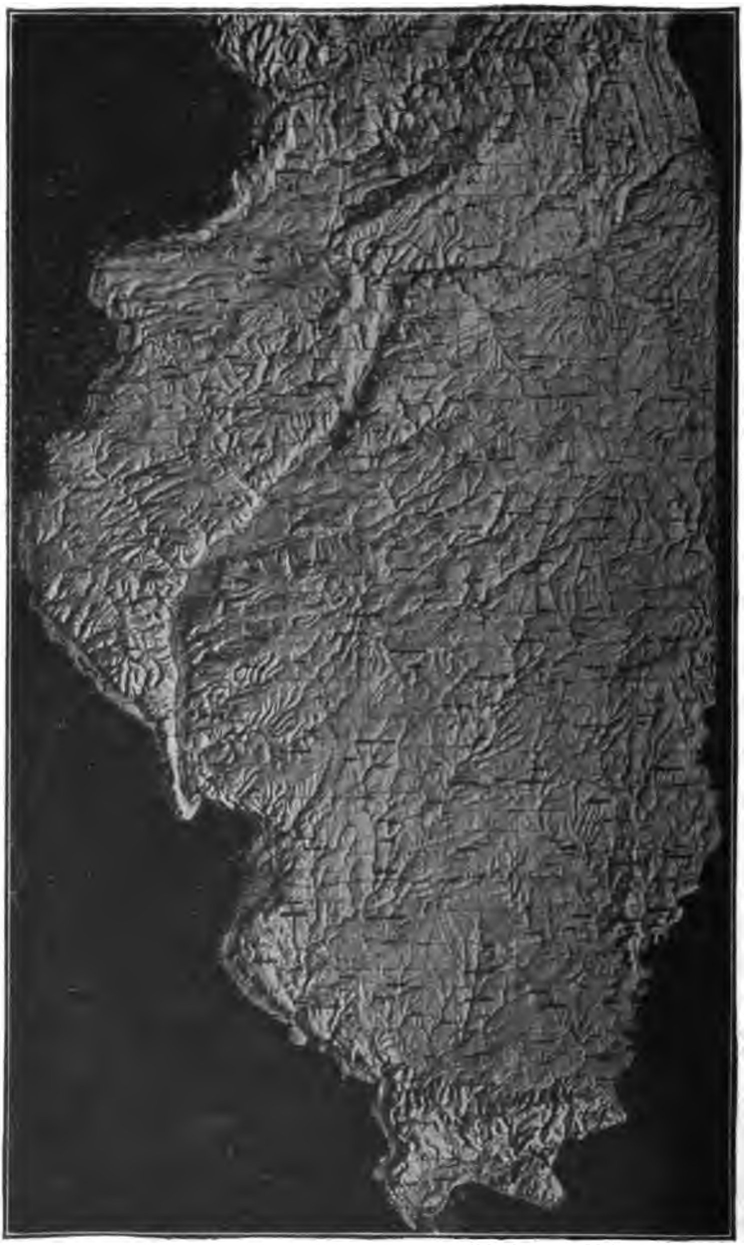

(M. Lorenz, Maker)

RELIEF MAP OF ILLINOIS

CLIMATE OF ILLINOIS

By J. G. MOSIER, Chief in Soil Physics

Illinois is so situated that its northern boundary is 2½ degrees south of the center of the north temperate zone, while its southern extremity is only 13½ degrees from the torrid zone. It extends over 5½ degrees of latitude, with a difference of about 2 degrees in mean temperature for each degree in latitude. The altitude varies from 310 feet in the extreme southern part of the state to 1,257 feet in Jo Daviess county, the highest point in the state. The Ozark Ridge, extending east and west across the state near the southern end, reaches an altitude of 1,046 feet in the northwestern part of Pope county. About 70 percent of the state lies between 500 and 700 feet above sea level.

The state is entirely within the belt of prevailing westerly winds with their accompanying cyclones, or "lows," and anticyclones, or "highs." To these "lows" and "highs," as they are commonly designated by the forecaster and on the weather map, is due the ordinary weather of the state. As our weather changes are almost entirely due to the passage of cyclonic storms across the country, their importance requires some notice here.

WEATHER CHANGES PRODUCED BY CYCLONES, OR LOWS, AND ANTICYCLONES, OR HIGHS

A cyclone, or low, is a storm having an atmospheric pressure lower than the normal due to the rising of the air in the storm area. Since a cyclone is a whirling storm, or whirlwind, the wind does not blow directly in toward the center of the low, but somewhat spirally and counter-clockwise. As the low passes eastward, the wind changes to the northwest, either thru the southwest or the northeast, depending upon the part of the low passing over the locality. If the center of the low is to the north, then the wind shifts to the south, the southwest, and finally to the northwest. If the center of the low is to the south, the wind shifts to the northwest thru the northeast and north. In either case, when the wind becomes northwesterly the temperature becomes lower. When the center of the low passes over a locality, there is usually a sudden change of the wind to a westerly or northwesterly direction, with an accompanying change in temperature. Clearing weather usually follows the passage of the center, and the rear of the low is marked by cooler, clear weather.

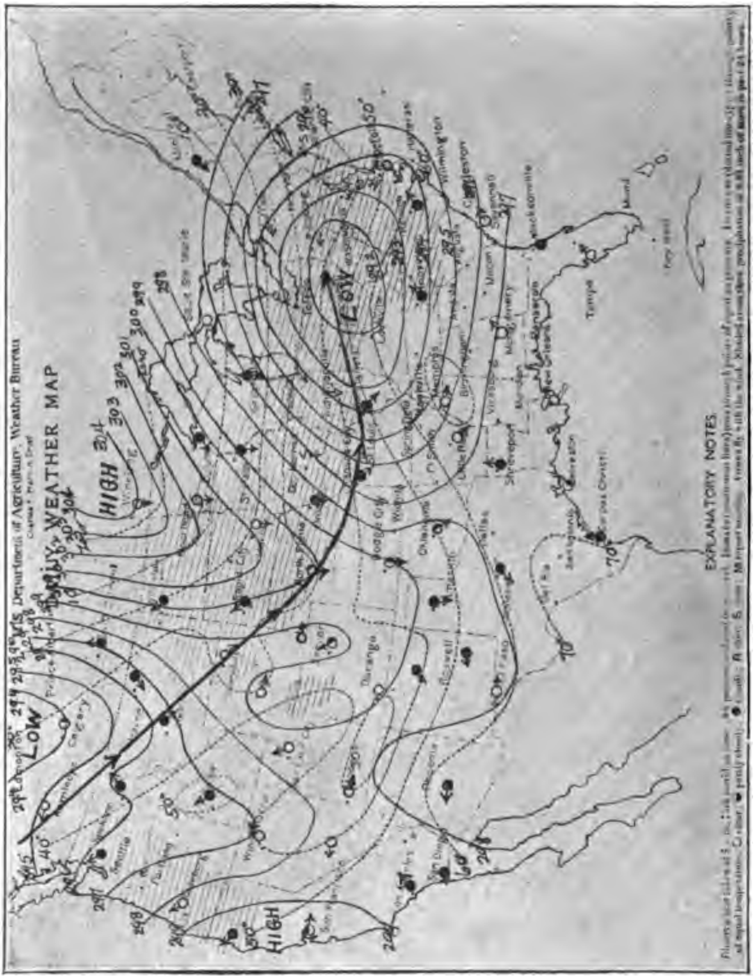

FIG. 1.—WEATHER MAP FOR MARCH 22, 1916
The long, heavy arrows show the course of the low. The spaces between the arrow points show 12-hour periods. This represents a very common path for lows to take.

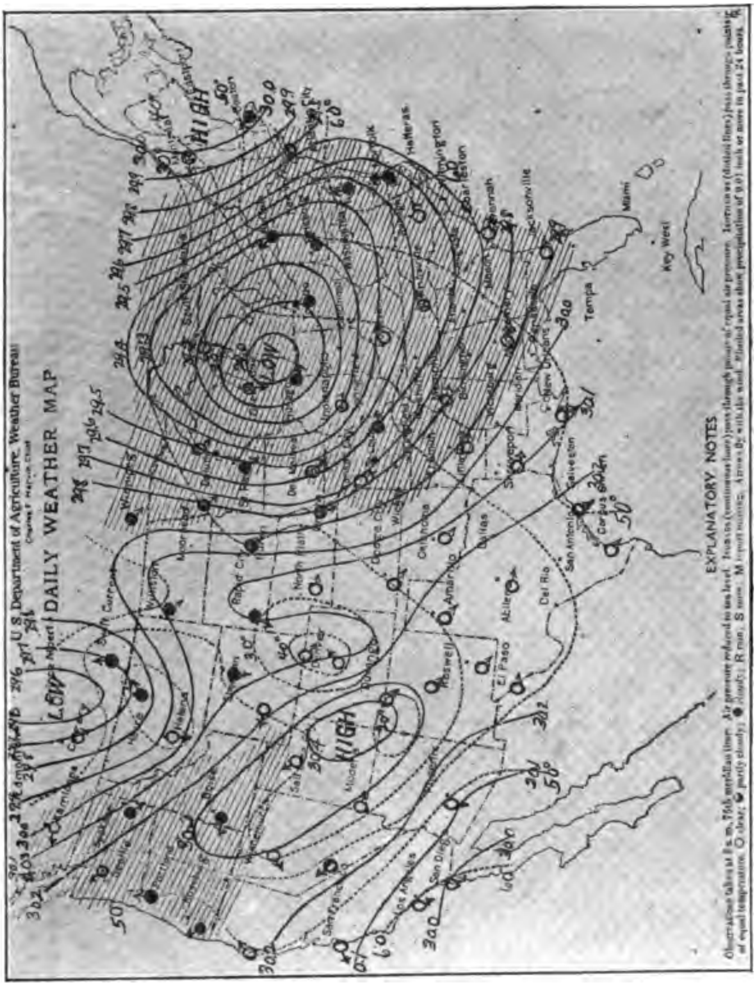

FIG. 2.—WEATHER MAP OF NOVEMBER 19, 1915
Note the direction of the wind in the different parts of the cyclonic area; also the isotherms (equal temperature lines) and isobars (equal atmospheric pressure lines). Where the isobars are close together, high winds prevail.

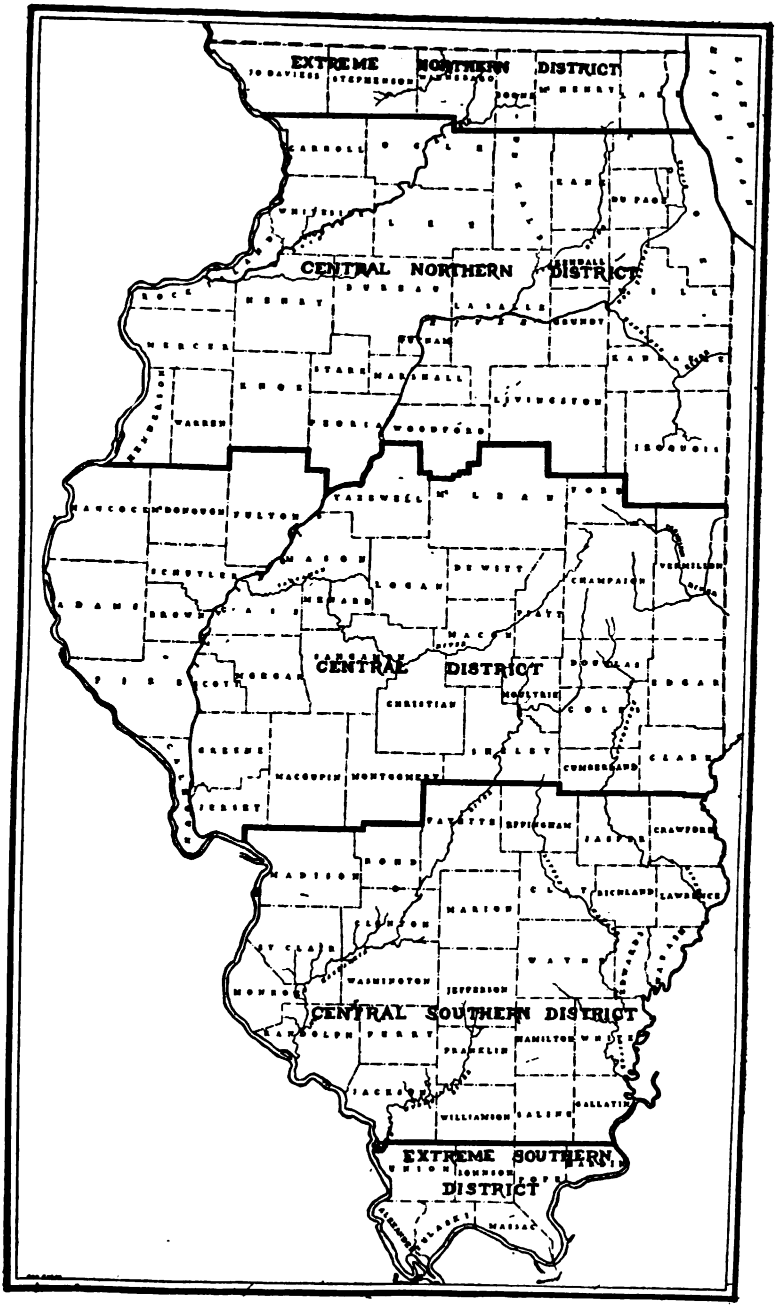

FIG. 3.—MAP OF ILLINOIS SHOWING DIVISION INTO DISTRICTS

By knowing the direction and the rate of movement of these cyclones, one may plan his work so as to avoid being taken unawares by many of these storms. The daily weather map or even the daily paper will give valuable information in regard to their movement. If rain is predicted within twenty-four hours for Kansas, Nebraska, Missouri, or Iowa, the chances are that within thirty-six hours the same condition will prevail in Illinois.

DISTRICTS OF THE STATE

For convenience the state has been divided into five districts as follows:

(1) Extreme northern district, including the tier of counties along the Wisconsin line.

(2) Central-northern district, including the counties between the extreme northern division and an irregular line extending across the state on the southern lines of Henderson, Warren, Knox, Peoria, Woodford, Livingston, and Iroquois counties (crossing Ford).

(3) Central district, including the counties between the southern boundary of the central-northern district and a line on the south boundary of Jersey, Macoupin, Montgomery, Shelby, Cumberland, and Clark counties.

(4) Central-southern district, including the counties south of the central district and north of the Ozark Ridge.

(5) Extreme southern district, including the seven most southern counties.

The extreme northern district includes counties that are on the border of the corn belt. The central-northern and the central divisions include the corn belt proper, while the central-southern includes practically all that portion of the state in the lower Illinoisan glaciation. (See general soil map of Illinois in Bulletin 193). The seven southern counties are unglaciated and form a distinct soil and physiographic region by themselves.

RAINFALL

The primary cause for precipitation is the condensation of vapor in the atmosphere as a result of the lowering of the temperature. This change in temperature may be brought about by a current of moist air rising to a higher altitude, by a warm vapor-laden air current meeting a cold one, or by movement of the air from warmer to cooler regions, as from tropical to temperate regions. The amount of precipitation depends upon the extent of the cooling and the amount of vapor carried in the air. In general, the amount of precipitation diminishes as distance from the equator increases. Many local variations occur, however, that are due to differences of altitude, direction of wind, etc. These variations may produce extremely heavy rainfall over small areas and at certain seasons.

The distribution of the rainfall by months varies with the different sections of the state, as shown by the diagram on page 21. In the extreme northern and central-northern districts the six months April to September form the period of greatest rainfall, while in the extreme southern district the precipitation is more evenly distributed, with August, September, and October as the driest months.

RELATION OF RAINFALL TO CROPS

Two factors of climate are of special importance in the growth of crops. These are precipitation and temperature. The supply of moisture for the soil and the crop is derived entirely from precipitation either as snow or as rain. No large excess is needed, and we are frequently surprised at the size of crops that may be grown with a small, well-distributed rainfall. From 300 to 500 pounds of water are required by the plant in order that it may produce one pound of dry matter. A 100-bushel crop of corn requires for its production about 16 inches of water, or about 18 tons for each bushel of shelled corn weighing 56 pounds. A 100-bushel crop of oats requires 18 inches, or 20 tons for a bushel of grain, and a ton of clover hay requires about 450 tons of water.

There is sufficient rainfall almost every year to produce maximum crops. The difficulty is with its distribution. The average yearly rainfall for the state is 37.98 inches, or more than 3 inches per month, but during the ten years from 1906 to 1915 at the University of Illinois there have been twenty-five periods of 20 days or longer in which the rainfall has been less than one inch. Of these dry periods, six have been 30 days or more in length. The injury resulting from the irregularity in the distribution of the rainfall may be prevented to some extent by drainage, tillage, increasing and maintaining the organic matter of soils, and keeping the soils well supplied with plant food.

This uneven distribution of the rainfall is a sufficient incentive to cause the farmer to take every precaution for storing and holding the moisture in the soil before the crop is planted by preparing a deep, mellow seed bed, or for carrying off quickly excessive amounts of rain. Corn should receive an average of at least 2.5 inches of rainfall per month during the three months of its growth. The effects of rainfall during June, July, and August upon corn yields are shown by the records of the old continuous corn plot at the University. Corn has been grown on this plot since 1879, but there is no record of the yields previous to 1889.

Summer rainfall
  —Less than 7 inches................25.3 bu. per acre (8-year av.)
  —Between 7 and 10 inches..........32.4 bu. per acre (9-year av.)
  —Over 10 inches...................39.8 bu. per acre (11-year av.)

When the rainfall was less than two inches per month, the yield was reduced, for a four-year average, to 24.4 bushels per acre, and when the rainfall was over thirteen inches, the yield was 45.9 bushels per acre, for a seven-year average. This is a difference of 21.5 bushels between yields produced with what might be called the maximum rainfall and those produced with the minimum, at the University of Illinois. It is evident from this that a month during which there is less than two inches of rainfall may be regarded as a dry month.

EXTREME NORTHERN DISTRICT

The average annual precipitation for the extreme northern district is 33.99 inches, as shown by the records for the fifty years from 1866 to 1915. This is 9.29 inches less than the average for the extreme southern district. However, the rainfall in this district is better distributed for the growing of crops than is that in any other part of the state—a fact which about compensates for the smaller total. From March to August the average rainfall is 20.56 inches, or 60.4 percent of the average annual rainfall. During the winter the average rainfall is 5.44 inches; during spring, 9.34 inches, during summer, 11.22 inches; and during fall, 7.99 inches.

June is the month of greatest rainfall, while May has an average of only .07 inch less. During the last twenty years, however, May has had an average of over one inch more than June. February and December have the least precipitation. The highest average monthly rainfall for any ten-year period was 5.03 inches for June, 1876-1885, while July of the same period follows with 4.88 inches, and May, 1906-1915, with 4.63 inches, is next.

The lowest average monthly precipitation for a ten-year period was 1.34 inches for December, 1896-1905. The lowest rainfall recorded for any month during the growing season was .10 inch at Winnebago, for August, 1889, while the heaviest was 15.73 inches at Riley, for September, 1894.

TABLE 1.—AVERAGE MONTHLY AND YEARLY PRECIPITATION: EXTREME NORTHERN DISTRICT
10–, 20–, 30–, AND 50–YEAR PERIODS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1866–1875........	2.03	1.20	2.22	2.51	3.13	4.21	3.06	3.38	4.03	1.83	1.68	1.85	31.13
1876–1885........	1.81	2.23	2.63	3.18	3.74	5.03	4.88	3.40	3.12	3.90	2.63	2.14	38.69
1886–1895........	2.60	1.99	2.42	3.04	4.39	4.46	2.60	2.94	2.73	2.19	2.17	2.01	33.54
1896–1905........	1.45	1.73	2.94	2.68	4.38	3.33	4.35	3.45	3.59	2.17	1.52	1.34	32.93
1906–1915........	1.76	1.64	1.86	3.01	4.63	3.59	3.26	4.20	4.04	2.13	2.23	1.41	33.76
1866–1885........	1.92	1.72	2.43	2.85	3.44	4.62	3.97	3.39	3.58	2.87	2.16	2.00	34.95
1886–1915........	1.94	1.79	2.41	2.91	4.47	3.79	3.40	3.53	3.45	2.16	1.97	1.59	33.41
1866–1915........	1.93	1.76	2.41	2.88	4.05	4.12	3.63	3.47	3.50	2.44	2.05	1.75	33.99

TABLE 2.—AVERAGE MONTHLY AND YEARLY PRECIPITATION: CENTRAL-NORTHERN DISTRICT
10–, 30–, AND 60-YEAR PERIODS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1856–1865........	1.85	2.13	2.78	3.42	3.57	3.23	4.07	3.50	3.54	2.54	2.34	2.65	35.62
1866–1875........	2.05	1.44	2.53	2.79	3.92	3.51	3.63	3.69	3.58	1.97	2.00	2.01	33.12
1876–1885........	1.64	2.44	2.52	3.42	4.00	5.11	3.85	3.38	2.79	4.09	2.75	2.13	38.12
1886–1895........	2.06	1.92	2.32	2.80	4.23	3.75	2.94	2.39	2.98	1.84	2.41	2.17	31.81
1896–1905........	1.80	1.82	3.10	2.66	4.08	3.80	4.01	3.68	3.81	1.93	1.84	1.34	33.87
1906–1915........	1.88	1.85	2.01	2.96	4.48	3.02	3.38	3.52	4.05	2.04	2.13	1.61	32.93
1856–1885........	1.85	2.00	2.61	3.21	3.83	3.95	3.85	3.52	3.30	2.87	2.36	2.26	35.61
1886–1915........	1.91	1.87	2.48	2.81	4.26	3.52	3.44	3.20	3.61	1.94	2.13	1.71	32.88
1856–1915........	1.88	1.93	2.54	3.01	4.05	3.74	3.65	3.36	3.46	2.40	2.25	1.99	34.26

About two out of every five Marches are relatively dry, having less than two inches of rain, while one April in every four is dry. May once in eight years is dry, June twice in thirteen years, July once in five years, and August twice in eight years. The greatest range in the average annual rainfall during the fifty years has been 27.11 inches—from 22.20 inches in 1901 to 49.31 inches in 1892.

CENTRAL-NORTHERN DISTRICT

For the central-northern district the records of the sixty years from 1856 to 1915 show an average annual rainfall of 34.26 inches. This is only .27 inch more than the rainfall for the extreme northern district. From March to August the central-northern district receives 20.35 inches, or 59.4 percent of its rainfall. The average precipitation in winter is 5.80 inches; in spring, 9.60 inches; in summer, 10.75 inches; and in fall, 8.11 inches. The lowest annual rainfall recorded was 23.17 inches in 1901, and the highest 49.25 inches in 1902.

May is the month of greatest rainfall, with an average of 4.05 inches, and June is next, with 3.74 inches. The highest average rainfall for a period of ten years occurred in June from 1876 to 1885, the average being 5.11 inches. May follows with 4.48 inches as an average of the years 1906 to 1915.

January is the month of lowest rainfall, the average for the sixty years being 1.88 inches. Among the ten-year averages, the month of December during the years 1896 to 1905 is the lowest, with 1.34 inches, while February is next with 1.44 inches as an average of the years 1866 to 1875.

The recurrence of dry periods is about the same as in the extreme northern district. One-third of the Marches are dry, having less than two inches of rainfall; also one-fourth of the Aprils, one-tenth of the Mays, one-ninth of the Junes, two-elevenths of the Julys, and two-ninths of the Augusts. The lowest rainfall recorded at any of the twenty-three stations of this district during the growing season was .10 inch at Aledo in July, 1913, and the same amount at Lanark in April, 1915. The heaviest rainfall for any month was 20.03 inches at Monmouth in September, 1911.

CENTRAL DISTRICT

The annual rainfall of the central district is 36.89 inches as an average of the sixty years during which records have been kept. This is about two inches more than that of the districts to the north. The highest ten-year average was 40.54 inches for the years 1876 to 1885, while the lowest was 34.11 inches for the years 1886 to 1895—a difference of 6.43 inches. From March to August the average precipitation is 21.47 inches, or 58.4 percent, of the yearly rainfall. During the

TABLE 3.—AVERAGE MONTHLY AND YEARLY PRECIPITATION: CENTRAL DISTRICT
10–, 30–, AND 60-YEAR PERIODS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1856–1865........	2.08	2.93	2.93	4.03	3.54	3.99	4.10	2.37	3.74	2.60	2.19	2.68	37.18
1866–1875........	2.36	1.91	2.88	3.35	3.91	3.87	4.98	3.11	3.55	2.48	1.99	2.33	36.72
1876–1885........	1.67	2.99	3.04	3.32	4.17	5.50	3.51	3.46	3.46	4.10	2.86	2.46	40.54
1886–1895........	2.08	2.42	2.53	3.49	4.26	3.71	3.06	2.55	3.22	1.33	3.26	2.20	34.11
1896–1905........	2.22	2.10	3.60	2.98	4.10	4.27	3.88	3.41	3.59	2.39	2.16	1.86	36.56
1906–1915........	2.53	2.19	2.54	3.65	4.27	3.33	3.83	3.33	4.03	2.17	2.46	1.88	36.21
1856–1885........	2.04	2.61	2.95	3.57	3.87	4.45	4.20	2.98	3.58	3.06	2.35	2.49	38.15
1886–1915........	2.28	2.24	2.89	3.37	4.21	3.77	3.59	3.10	3.61	1.96	2.63	1.98	35.63
1856–1915........	2.16	2.42	2.92	3.47	4.04	4.11	3.89	3.04	3.60	2.51	2.49	2.24	36.89

TABLE 4.—AVERAGE MONTHLY AND YEARLY PRECIPITATION: CENTRAL-SOUTHERN DISTRICT
10–, 30–, AND 60-YEAR PERIODS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1856–1865........	2.19	3.03	3.76	3.85	4.40	4.25	4.29	3.65	3.30	3.04	3.17	3.75	42.68
1866–1875........	2.52	2.61	3.75	3.59	4.76	4.66	5.18	4.05	3.09	2.15	2.45	3.10	41.91
1876–1885........	3.01	3.55	3.09	3.53	4.13	5.20	3.55	3.16	3.46	3.91	3.57	3.09	43.25
1886–1895........	2.89	3.15	3.38	4.22	4.07	4.05	2.81	3.18	2.98	1.50	4.09	2.49	38.81
1896–1905........	2.61	2.49	5.41	3.14	4.01	4.36	4.05	2.79	3.01	2.68	2.75	2.69	39.99
1906–1915........	3.83	3.15	3.66	3.99	3.78	3.65	3.66	4.00	4.01	2.89	3.01	2.65	42.28
1856–1885........	2.57	3.06	3.53	3.66	4.43	4.70	4.34	3.62	3.28	3.03	3.06	3.31	42.59
1886–1915........	3.11	2.93	4.15	3.78	3.95	4.02	3.51	3.32	3.33	2.36	3.28	2.61	40.36
1856–1915........	2.84	3.00	3.84	3.72	4.19	4.36	3.92	3.47	3.31	2.70	3.17	2.96	41.48

winter months there is an average rainfall of 6.82 inches; during the spring months, 10.43 inches; during the summer 11.04 inches; and during the fall, 8.60 inches. The lowest precipitation for any one year was 24.12 inches in 1879. In 1901 the total rainfall was 26.43 inches; and in 1914, 25.83 inches. The greatest annual rainfall was 48.24 inches in 1876.

June is the month of highest average rainfall, with 4.11 inches. May and July follow closely with 4.04 and 3.89 inches. The highest average monthly rainfall for a ten-year period was 5.50 inches for June, 1876-1885. July follows with 4.98 inches in the period from 1866 to 1875.

January is the month of lowest precipitation, with an average of 2.16 inches. December follows with 2.24 inches, and February with 2.42 inches. October shows the lowest ten-year average rainfall, 1.33 inches for the period 1886 to 1895, while January follows with 1.67 inches for the ten years 1876 to 1885.

The recurrence of dry months is about as frequent as in the northern districts. As an average, one dry March occurs every three years, two dry Aprils every eleven years, one dry May every six years, one dry June every ten years, two dry Julys every thirteen years, and one dry August every four years.

The lowest rainfall recorded in any month from April to September for this district was a trace at Carlinville and at Hillsboro in September, 1897. At Carlinville there was .16 inch in July, 1886, and .10 inch in September, 1883. The heaviest rainfall recorded for any month during the sixty years was 14.77 inches for June, 1915, at Griggsville.

CENTRAL-SOUTHERN DISTRICT

The average annual rainfall of the central-southern district, as shown by the records for sixty years, is 41.48 inches, or 4.59 inches more than the central district for the same period and 7.22 inches more than the central-northern district. The highest ten-year annual average was 43.25 inches for the years 1876 to 1885, while the lowest was 38.81 inches for 1886 to 1895. The lowest rainfall for any one year was 29.44 inches in 1901. In 1871 the rainfall was but 30.01 inches. The highest annual rainfall was 59.95 inches in 1858. From March to August there is an average precipitation of 23.50 inches, or 56.6 percent of the average yearly rainfall. The winter rainfall is 8.80 inches; that of spring, 11.75 inches; that of summer, 11.75 inches; and that of fall, 9.18 inches.

June is the month of highest average rainfall, with 4.36 inches, while May is next with 4.19 inches. June shows the highest ten-year average, 5.20 inches during the period from 1876 to 1885. July comes next with 5.18 inches for the years 1866 to 1875.

October is the month of lowest rainfall, with an average of 2.70 inches. For this month is recorded also the lowest precipitation for a

TABLE 5.—AVERAGE MONTHLY AND YEARLY PRECIPITATION: EXTREME SOUTHERN DISTRICT
10-, 20-, 30-, AND 50-YEAR PERIODS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1866–1875........	2.46	3.94	5.20	4.01	3.78	3.38	3.33	1.92	2.79	1.91	3.23	3.04	38.99
1876–1885........	4.53	4.23	3.70	4.02	4.90	5.53	3.72	4.01	3.13	4.00	4.14	4.08	49.99
1886–1895........	3.41	3.39	3.82	3.59	3.54	4.09	2.70	3.06	2.61	1.90	4.98	2.82	39.91
1896–1905........	3.26	2.65	5.30	3.71	4.38	4.14	3.94	2.54	2.80	2.90	2.90	3.46	41.98
1906–1915........	4.58	3.86	3.88	4.75	3.28	3.10	4.13	3.90	3.64	3.29	3.48	3.62	45.51
1866–1885........	3.50	4.09	4.45	4.02	4.34	4.46	3.53	2.97	2.96	2.96	3.69	3.56	44.53
1886–1915........	3.75	3.30	4.33	4.02	3.73	3.78	3.59	3.17	3.02	2.70	3.79	3.30	42.48
1866–1915........	3.65	3.61	4.38	4.02	3.98	4.05	3.56	3.09	2.99	2.80	3.75	3.40	43.28

ten-year period, the average for the years 1886 to 1895 having been only 1.50 inches.

The recurrence of months with less than two inches of rainfall is less frequent in this district than in the central district and other districts farther to the north. The greater injurious effects from drouth are due almost entirely to soil conditions. Time will be required to remedy these. Heavy applications of limestone must be made, deep-rooting crops must be grown to loosen the subsoil, and organic matter of every available kind must be incorporated with the soil. This will put the soil in better condition to absorb and retain moisture.

As an average, two Marches in every fifteen years are dry, two Aprils in every nine years, one May in every twelve years, one June in every twelve years, one July in every ten years, and one August in every five years.

The lightest rainfall recorded in this district, for any one month during the growing season, was a trace in April, 1915, at Fairfield, and the same in August, 1909, at Carlyle. The greatest rainfall was 15.30 inches in July, 1875, at Flora. The heaviest monthly rainfall recorded at St. Louis, Missouri, was 17.07 inches in June, 1848.

EXTREME SOUTHERN DISTRICT

The extreme southern district includes the Ozark Ridge region and some extensive bottom lands. Records for the fifty years from 1866 to 1915 show the average annual rainfall to be 43.28 inches, which is 9.29 inches more than that of the extreme northern district for the same period. From March to August the average rainfall is 23.08 inches, or 53.3 percent of the average annual rainfall. During the winter months it is 10.66 inches; during the spring, 12.38 inches; during summer, 10.70 inches; and during fall, 9.54 inches. The lowest annual rainfall was 26.52 inches in 1872, while the greatest was 62.89 inches in 1882.

March is the month of greatest rainfall, having an average for fifty years of 4.38 inches. June is next with 4.05 inches. The highest average monthly rainfall for a ten-year period was 5.53 inches for June in the years 1876 to 1885.

October is the month of lowest rainfall, with an average of only 2.80 inches. The lowest average monthly rainfall for a ten-year period was 1.90 inches for October during the years 1886 to 1895. From 1866 to 1875 an average of only 1.91 inches of rain fell during October.

Months of low rainfall are no more common in this district than in the northern districts. One in every seven Marches is dry, or has less than two inches of rain, one in ten Aprils, two in eleven Mays,

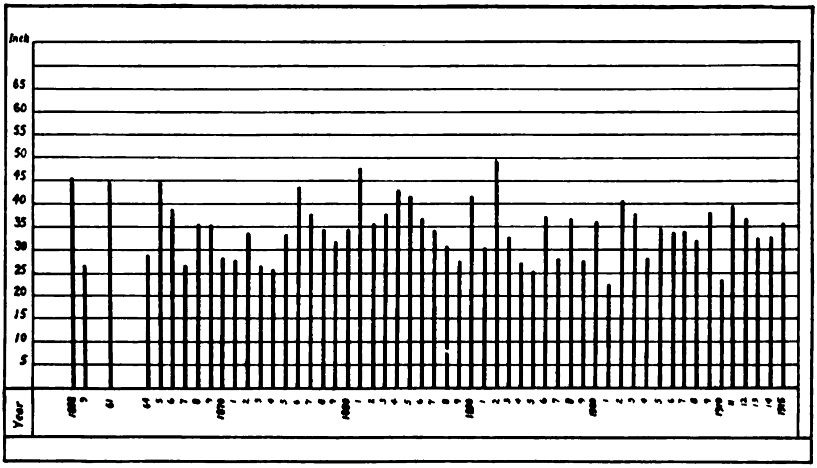

FIG. 4.—ANNUAL PRECIPITATION FOR EXTREME NORTHERN DISTRICT DURING FIFTY-EIGHT YEARS

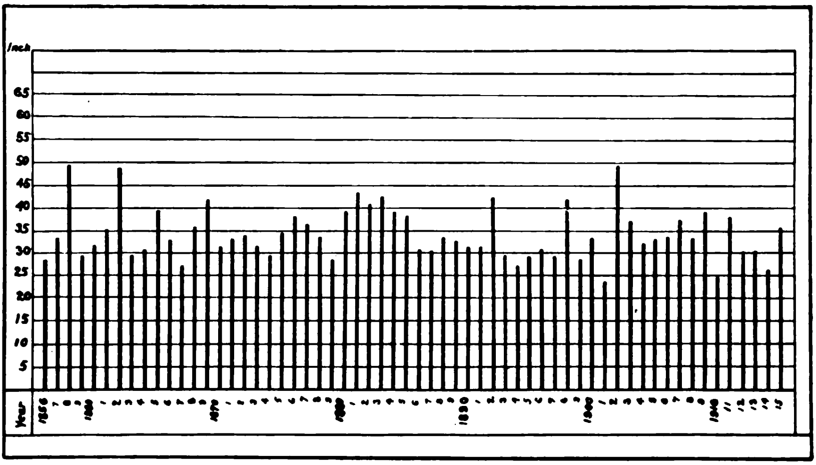

FIG. 5.—ANNUAL PRECIPITATION FOR CENTRAL-NORTHERN DISTRICT DURING SIXTY YEARS

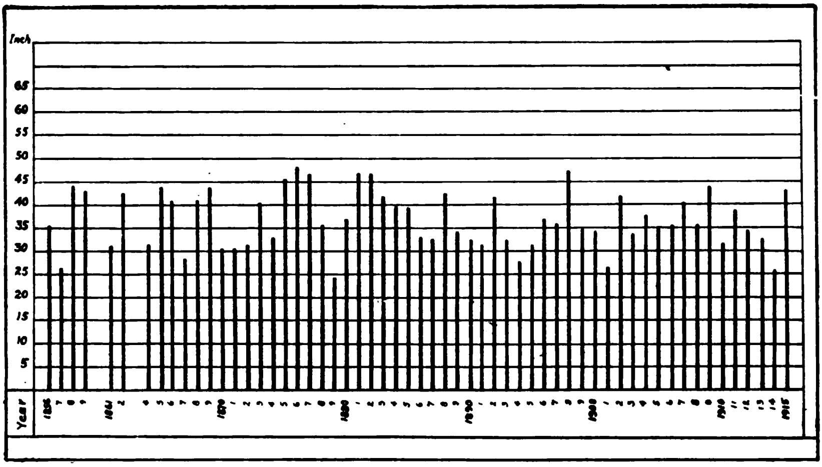

FIG. 6.—ANNUAL PRECIPITATION FOR CENTRAL DISTRICT DURING FIFTY-NINE YEARS

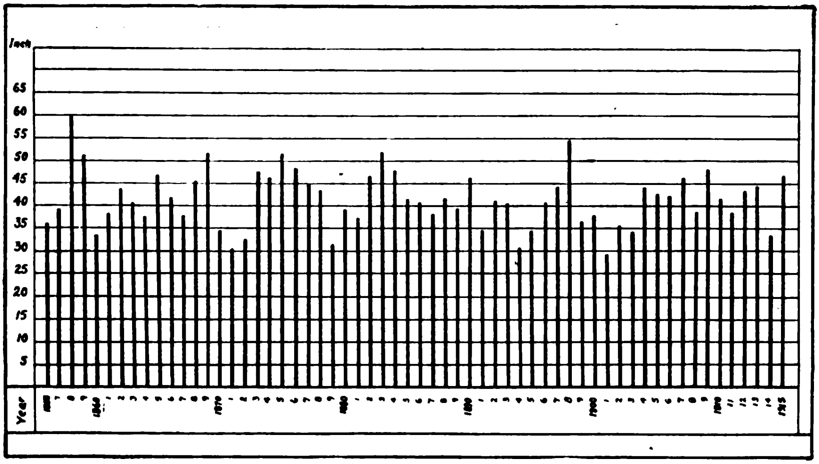

FIG. 7.—ANNUAL PRECIPITATION FOR CENTRAL-SOUTHERN DISTRICT DURING SIXTY YEARS

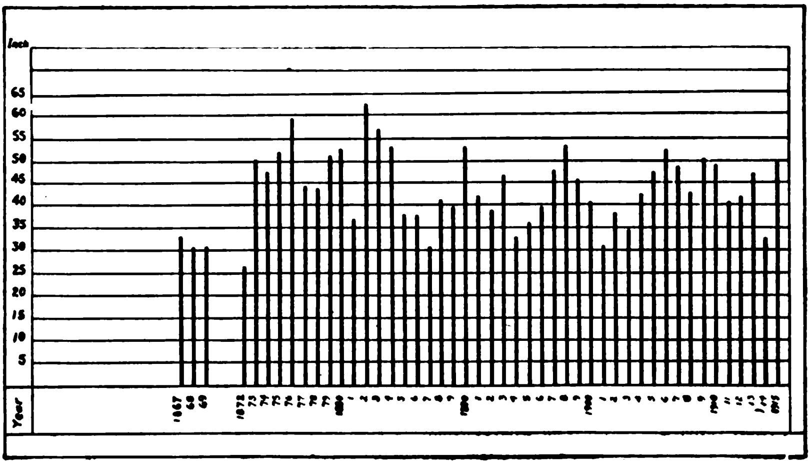

FIG. 8.—ANNUAL PRECIPITATION FOR EXTREME SOUTHERN DISTRICT DURING FORTY-SEVEN YEARS

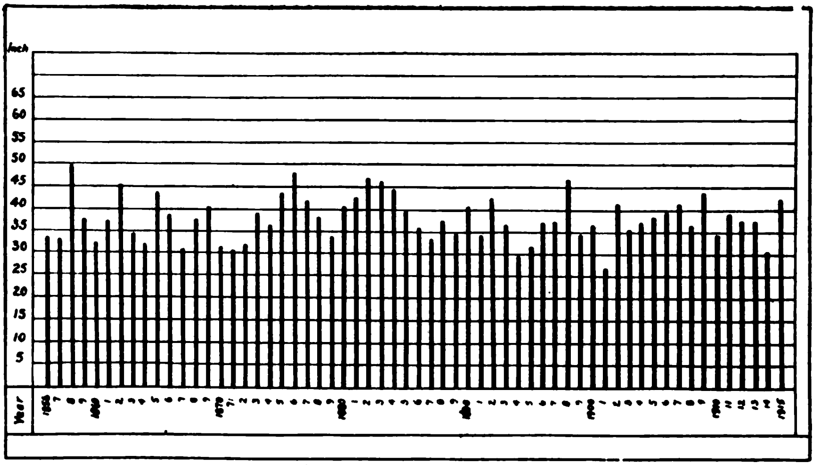

FIG. 9.—ANNUAL PRECIPITATION FOR STATE AS A WHOLE DURING SIXTY YEARS

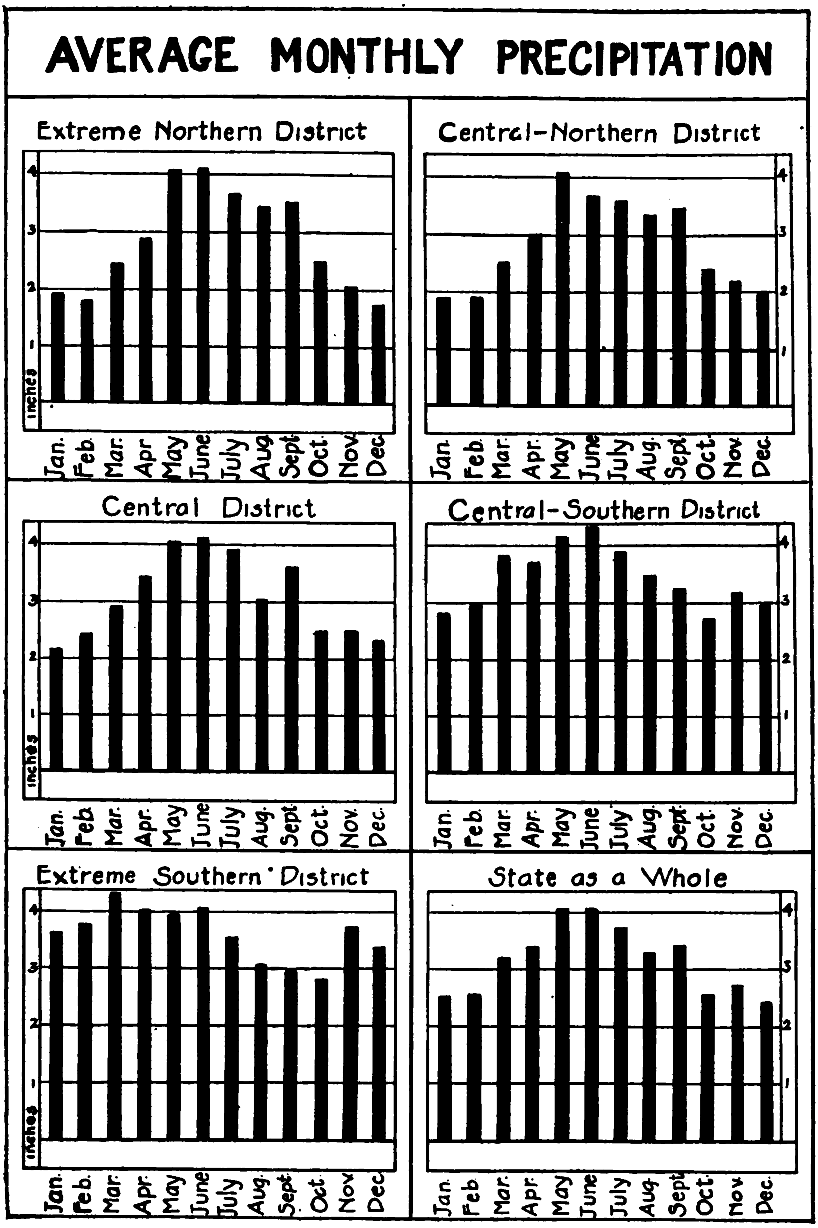

FIG. 10.—AVERAGE MONTHLY PRECIPITATION FOR THE DISTRICTS OF THE STATE AND FOR THE STATE AS A WHOLE

For the state as a whole, January averages 2.49 inches; February, 2.54; March, 3.22; April, 3.42; May, 4.06; June, 4.08; July, 3.73; August, 3.29; September, 3.37; October, 2.57; November, 2.74; December, 2.47; yearly total, 37.98.

one in six Junes, two in nine Julys, and one in three Augusts. The heaviest rainfall recorded for any one month was 15.46 inches in October, 1910, at Golconda. The least for any one month was only a trace at New Burnside in October, 1908, and in January, 1911.

SEASONAL RAINFALL

The comparative distribution of the seasonal rainfall is well shown in Table 6, where it is expressed both in inches and in percentage. Note the gradual increase of the winter precipitation from 5.44 inches in the northern part of the state to 10.66 inches in the southern part, and also the almost uniform summer precipitation thruout the state. The spring rainfall shows a very distinct increase southward; the autumn rainfall also increases southward but to a less degree. (The more severe effects of drouth in southern Illinois are very largely due to the character of the soil. The average temperature for July and August is only 1.7 degrees higher for the central-southern than for the central district, altho for January and February it is 4.3 degrees higher.)

TABLE 6.—SEASONAL RAINFALL

District	Winter		Spring		Summer		Autumn	
	inches	*percent*	*inches*	*percent*	*inches*	*percent*	*inches*	*percent*
Extreme northern...	5.44	16.0	9.34	27.4	11.22	33.0	7.99	23.6
Central-northern....	5.80	16.8	9.61	27.9	10.75	31.6	8.11	23.7
Central............	6.82	18.0	10.43	27.9	11.04	30.7	8.60	23.4
Central-southern....	8.80	21.2	11.75	28.3	11.75	28.3	9.18	22.2
Extreme southern...	10.66	24.8	12.38	28.5	10.70	24.7	9.54	22.0

SNOWFALL

The winter precipitation in the form of snow plays a very important part in crop production. The water from the melting snow sinks into the soil, if it is not frozen, with less run-off than there is with the same amount of rainfall. If the soil is frozen and the melting is rapid, much run-off occurs and is frequently accompanied by floods.

However, the greatest value of snow in humid regions is not the moisture it supplies to the soil, but the protection it affords the crops that live in the soil over winter, such as alfalfa, clover, and wheat. Snow prevents the alternate freezing and thawing which results in injury to the crops. Open winters are very damaging, especially where the soil is not well drained. When freezing occurs, the soil is frozen fast to the roots; when upward expansion takes place, the plant is raised; and when thawing occurs, the soil settles back but the plant does not. Repeated freezings cause the plant to be heaved from the soil. If the soil is well drained, the expansion of freezing will be taken care of largely

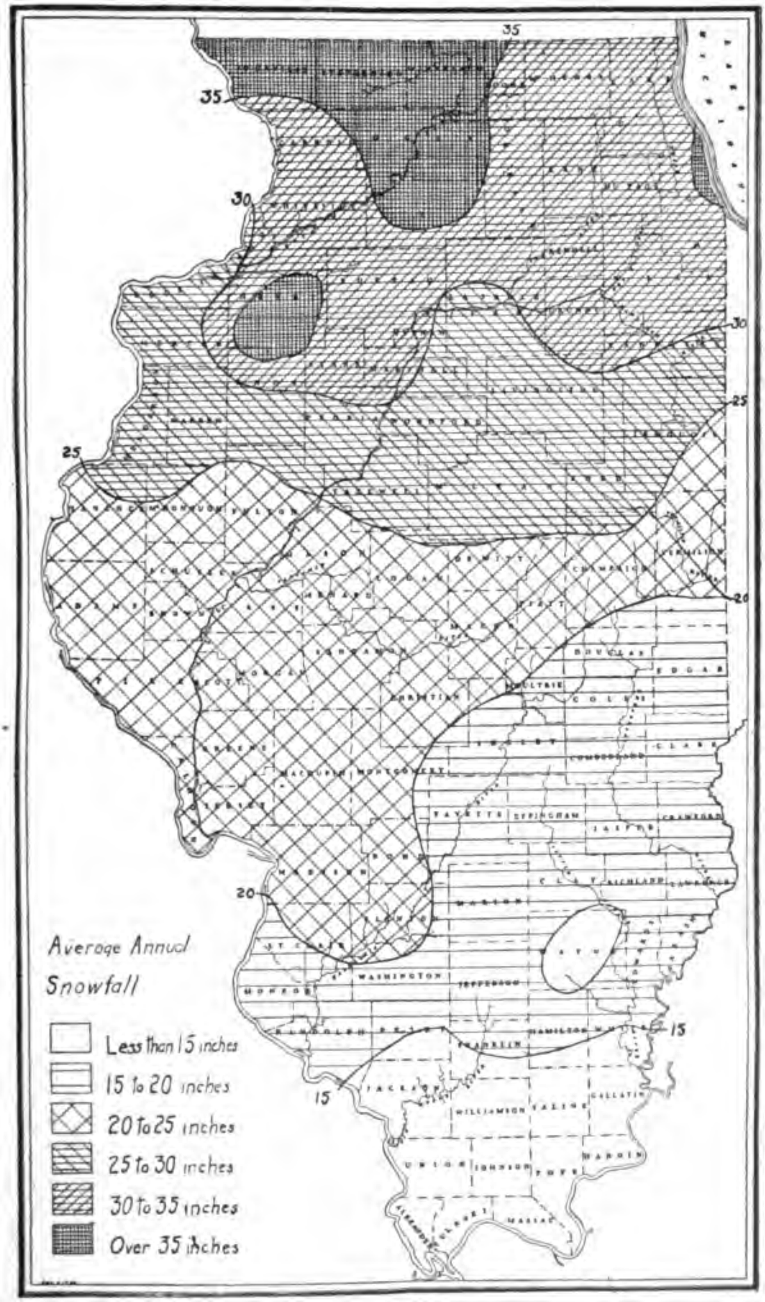

FIG. 11.—AVERAGE ANNUAL SNOWFALL
The average for the state is 24.7 inches

within the pore space of the soil itself, or the soil may not grip the plant with sufficient firmness to loosen the deeper roots.

Snow, being a poor conductor of heat, forms a very effective covering for the winter crops. During periods of intense cold the temperature of the soil one inch deep beneath the snow is much higher than the temperature of the air above. Experiments show that the temperature on top of a snow is from 11 to 15 degrees lower than the ground under a 4-inch snow.

The average annual snowfall for the central-southern and extreme southern districts is 17.5 inches; for the central, 23.3 inches; and for the central-northern and extreme northern, 31.7 inches. The average for the state is 24.7 inches.

One of the most important factors in the protection which the snow offers to a crop is its duration on the land. In the northern quarter of the state, snow remains on the ground during a large part of the winter, while in the central and southern districts it is the exception for it to remain more than a week.

TEMPERATURE

RELATION OF TEMPERATURE TO GROWTH OF CROPS

From the extreme northern to the extreme southern boundaries of Illinois there are eleven degrees of difference in mean temperature and four and one-half weeks difference in the length of the growing season. These differences produce a marked effect upon the character and the kinds of crops that are commonly grown in the state. Cotton may be produced in the extreme southern part, where the climate is moderated by the latitude and possibly also in some small degree by the pouring of floods of the warm waters from the Cumberland and Tennessee rivers into the Ohio river. In the north end of the state early-maturing varieties of corn must be planted, and even these are sometimes badly damaged by early frosts. The high temperatures in the south third of the state commonly prevent the successful growing of oats there, while in the extreme north oats are one of the most successful crops. The native vegetation, and especially the forest trees of the extreme sections, show very striking differences. The beech, the tulip, the gums, the post oak, and the water oak, for instance, are confined to the southern part of the state.

The first vital function of plants which is greatly influenced by temperature is that of germination. Seeds do not germinate well if the soil is too cold. Oats, wheat, rye, flax, and clover will germinate slowly at temperatures between 32° and 40° F., tho much higher temperatures are best. Corn requires a high temperature for quick germination. In a test by Haberlandt, eleven days at 51° F. were required for the sprout to show, while at 65° only three days were necessary. Germination should be as rapid as possible in order to lessen the danger from decay and the likelihood of attacks of fungi which destroy the seed.

TABLE 7.—DAYS REQUIRED FOR GERMINATION OF SEED (RADICLE TO APPEAR) AT VARIOUS SOIL TEMPERATURES

	40° F.	51° F.	60° F.	65° F.
Rye	4	2½	1	1
Wheat	6	3	2	1¾
Oats	7	3¾	2¾	2
Alfalfa	6	3¾	2¾	2
Red clover	7½	3	1¾	1
Flax	8	4½	2	2
Timothy	..	6½	3¼	3
Corn	..	11¼	3¼	3
Pumpkin	..	..	10¾	4

With many of our crops, such as rye, wheat, oats, alfalfa, sweet clover, and blue grass, growth takes place at very low temperatures. Wheat grows in winter, to a small extent, during the warm spells, and

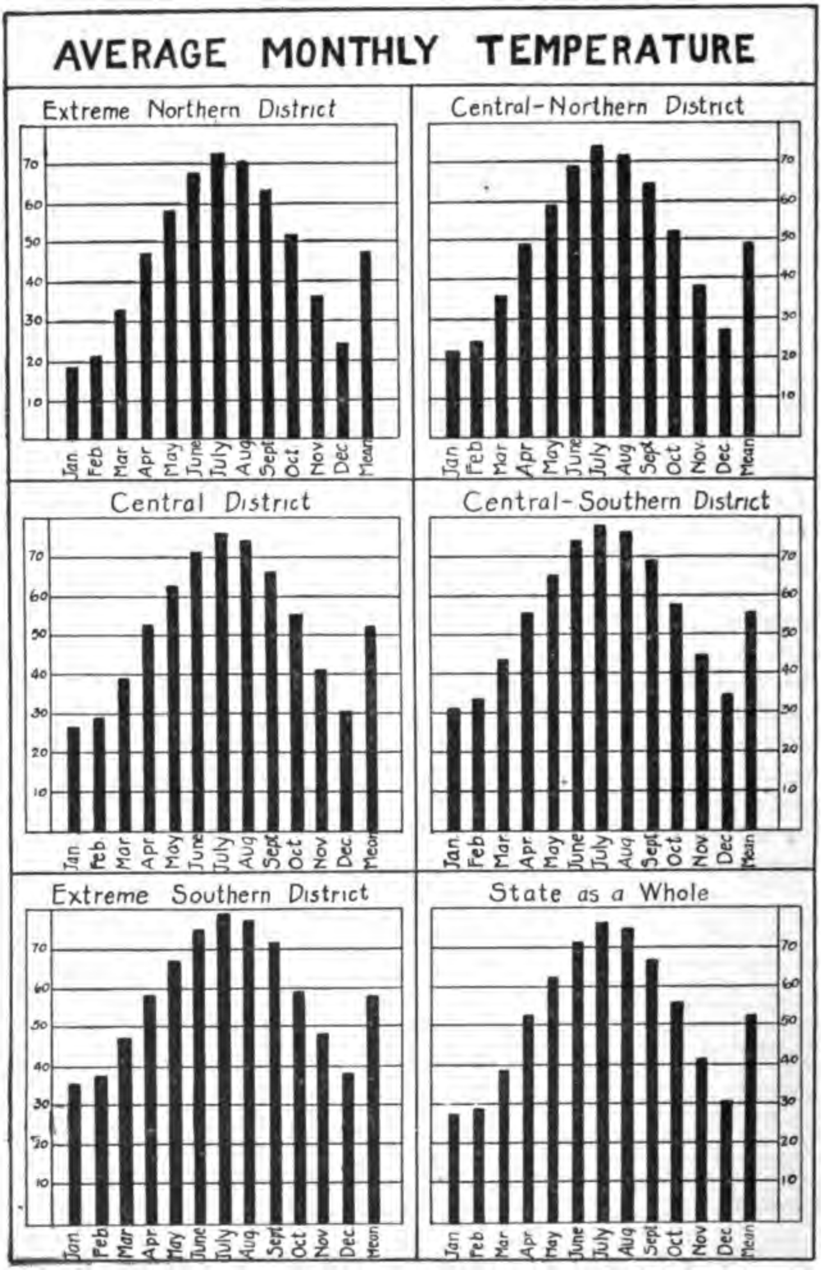

FIG. 12.—AVERAGE MONTHLY AND MEAN MONTHLY TEMPERATURES FOR THE DISTRICTS OF THE STATE AND FOR THE STATE AS A WHOLE

the common, and undoubtedly true, impression of farmers is that wheat makes some growth even under snow. Corn makes practically no growth below 49° F. For normal rapid growth the temperature of the soil must be 75° or above, at least during part of the day. Alfalfa shoots may start during the early days of March, while weeds may grow with temperatures but little above freezing. Mustard has been known to make some growth at 32° F.

The zero point for the growth of corn is 49°. This crop is more dependent upon the temperature of the soil than upon the temperature of the air above it. A cold soil produces slow growth and late maturity. This fact was markedly evident in 1915 in the corn crop. The average state temperature was below normal for the months that are of most consequence in the growing period. May was 2.5 degrees below normal, June 3.0 degrees, July 3.1 degrees, and August 6.1 degrees, while September was 1.4 degrees higher than normal. The result was that corn did not mature at the usual time and much of it was badly injured by frost even tho frost did not occur until October 6. The low temperature was very favorable for oats, which require less heat than corn.

For the production of crops a certain number of hours in which the temperature is above the "zero point of growth" is necessary. These are known as degree-hours and are ascertained by multiplying the number of hours during which the temperature is above the zero point of growth by the number of degrees the average temperature is above that point. Assuming that corn makes no growth below 49°, and that it is planted on May 20 and continues to grow until September 15, then the degree-hours which corn has for its development in the extreme northern district, as shown by the temperature records for the forty years from 1876 to 1915, is 57,910. For comparison with other districts, see Table 8.

TABLE 8.—AVERAGE NUMBER OF DEGREE-HOURS FOR THE GROWTH OF CORN IN THE VARIOUS DISTRICTS OF THE STATE

(Based on average air temperature from May 20 to September 15)

District	Degree-hours
Extreme northern	57 910
Central-northern	60 860
Central	67 240
Central-southern	72 600
Extreme southern	76 560

Table 9 gives the average number of degree-hours for the growing of corn, for the state as a whole, each year since 1876, together with the average yield of corn. Table 10 gives the same data for the Experiment Station.

TABLE 9.—RAINFALL, DEGREE-HOURS, AND AVERAGE YIELD OF CORN FOR ILLINOIS

Year	Rainfall				Degree-hours				Average corn yield per acre
	June	July	Aug.	Total	July	Aug.	Total July & Aug.	Total May 20–Sept. 15	
	inches	*inches*	*inches*	*inches*					*bu.*
1876	5.72	5.48	4.45	15.65	20 683	19 716	40 399	67 470	25.0
1877	5.64	3.36	2.95	11.95	20 385	18 674	39 059	66 150	30.0
1878	3.46	4.07	3.91	11.44	22 543	20 609	43 152	69 510	29.0
1879	4.08	3.58	4.91	12.57	21 948	18 005	39 953	66 090	38.0
1880	4.65	3.36	3.53	11.54	19 790	19 790	39 580	69 210	33.0
1881	5.94	3.30	.86	10.10	21 353	21 650	43 003	73 620	24.0
1882	6.39	3.53	4.15	14.07	16 963	17 707	34 670	57 930	24.0
1883	5.45	4.74	1.91	12.10	19 195	16 442	35 637	60 660	25.0
1884	5.04	4.61	2.67	12.32	18 749	16 740	35 489	62 660	33.0
1885	5.65	2.87	5.53	14.05	20 683	16 294	36 977	62 220	32.0
1886	3.76	1.16	3.87	8.79	20 386	19 642	40 028	65 710	25.0
1887	1.79	2.23	2.62	6.64	22 766	18 897	41 663	71 280	19.0
1888	4.47	3.85	4.16	12.48	20 609	17 335	37 944	63 380	39.0
1889	5.68	4.49	1.14	11.31	19 195	17 335	36 530	60 000	35.0
1890	5.21	1.63	3.26	10.10	20 460	16 666	37 126	67 110	27.0
1891	3.96	2.21	4.37	10.54	16 517	16 889	33 406	62 290	33.5
1892	6.57	3.71	3.41	13.69	19 121	18 377	37 498	64 900	26.2
1893	4.11	2.24	1.11	7.46	21 502	17 856	39 358	67 320	25.7
1894	1.97	1.41	1.84	5.22	20 609	19 642	40 251	71 420	28.8
1895	2.74	5.41	2.54	10.69	19 046	19 939	38 985	70 000	37.4
1896	4.13	5.54	2.66	12.33	20 237	19 790	40 027	68 890	40.5
1897	4.47	3.43	1.08	8.98	21 427	17 856	39 283	68 820	32.5
1898	4.16	3.54	4.35	12.05	20 162	18 823	38 985	69 100	30.0
1899	3.03	3.89	2.43	9.35	19 790	20 832	40 622	69 990	36.0
1900	4.94	4.27	3.53	12.74	19 939	23 138	43 077	69 960	37.0
1901	3.02	2.48	2.17	7.67	23 510	19 493	43 003	75 240	21.0
1902	6.87	4.50	3.86	15.23	20 460	17 410	37 870	63 730	38.7
1903	2.73	3.88	4.52	11.13	20 237	17 930	38 167	62 360	32.2
1904	3.04	4.17	3.70	10.91	18 228	16 591	34 819	61 190	36.5
1905	3.43	5.07	3.50	12.00	18 079	19 418	37 497	66 520	39.8
1906	3.18	2.69	4.37	10.24	18 526	20 386	38 902	67 840	36.1
1907	4.41	5.08	5.09	14.58	20 237	17 930	38 167	62 500	36.0
1908	2.82	3.28	2.54	8.64	19 939	18 898	38 837	67 040	31.6
1909	4.05	4.16	2.39	10.60	18 674	21 204	39 878	67 830	35.9
1910	2.26	4.51	2.91	9.68	21 055	18 302	39 357	64 870	39.1
1911	2.83	2.40	4.68	9.91	20 311	18 154	38 465	71 160	33.0
1912	3.67	4.64	3.87	12.18	20 014	17 707	37 721	65 210	40.0
1913	2.36	2.84	2.41	7.61	21 725	21 576	43 301	73 760	27.0
1914	3.07	1.40	3.36	7.83	22 246	19 939	42 185	73 200	29.0
1915	4.44	5.57	5.62	15.63	17 856	13 094	30 950	60 180	36.0
Av.	4.13	3.61	3.31	11.05	20 129	18 667	38 796	66 708	31.9

From 1876 to 1915 the average number of degree-hours for the state for the growing of corn was 66,708 per year. The highest number in any one season was 75,240 in 1901, and the lowest number was 57,930 in 1882. The average yield of corn for the state for the former year was 21 bushels and for the latter 24 bushels. During this forty-year period, twenty-one years have been above normal in number of degree-hours, with an average yield of 30.4 bushels of corn per acre, for the state, while nineteen years have been below normal, with an average yield of 33.6 bushels; showing that better yields are obtained when the temperature is slightly below normal.

TABLE 10.—RAINFALL, DEGREE-HOURS, AND YIELDS OF CONTINUOUS CORN PLOT AT ILLINOIS AGRICULTURAL EXPERIMENT STATION, URBANA

Year	Rainfall			Degree-hours			Degree-hours	Average corn yield per acre
	June	July	Aug.	June	July	Aug.	May 20–Sept. 15	
	inches	*inches*	*inches*					*bu.*
1889	6.81	5.81	.60	12 646	17 633	15 103	56 796	54.3
1890	3.80	2.83	1.93	18 432	17 856	14 657	59 350	43.2
1891	2.08	1.41	2.86	16 488	15 624	15 773	56 960	48.7
1892	5.36	2.50	2.45	15 552	17 079	16 730	57 840	33.1
1893	1.55	.59	.06	15 480	20 386	16 442	64 200	21.7
1894	1.78	1.08	2.06	17 568	18 451	17 335	56 750	34.8
1895	2.24	3.61	1.81	17 496	16 591	18 005	62 770	42.2
1896	2.98	7.87	3.74	15 264	18 451	17 112	62 760	62.3
1897	5.16	4.68	.63	14 760	19 939	15 624	63 696	40.1
1898	6.08	1.89	3.61	17 712	20 758	18 600	65 714	18.1
1899	2.29	2.65	2.29	16 128	18 898	19 567	67 717	50.1
1900	4.11	3.81	6.23	14 616	18 749	21 874	68 494	48.0
1901	5.80	2.48	1.68	16 704	22 692	18 451	69 261	23.7
1902	11.73	4.02	9.80	13 968	19 046	15 175	55 925	60.2
1903	2.56	5.13	2.33	11 160	19 195	16 814	58 475	26.0
1904	1.17	2.61	3.55	14 256	17 484	15 847	59 250	21.5
1905	1.30	5.40	2.14	15 912	17 782	19 121	59 095	24.7
1906	3.08	2.16	4.57	14 328	18 005	19 567	59 174	27.1
1907	5.56	5.41	4.42	12 744	18 749	16 517	56 973	29.0
1908	1.99	2.31	2.05	14 544	18 526	17 702	63 125	13.4
1909	3.75	7.57	2.37	15 264	16 368	19 642	60 658	26.6
1910	2.99	2.76	2.62	14 832	18 695	16 368	61 160	35.8
1911	.82	.62	3.35	18 288	19 567	17 856	71 445	21.8
1912	1.89	3.68	2.06	13 248	18 749	16 666	66 030	23.2
1913	1.67	1.52	1.44	16 920	21 725	21 204	79 380	19.4
1914	2.40	1.44	2.65	20 592	23 436	20 386	78 090	31.6
1915	2.98	7.30	4.90	15 552	18 674	13 690	60 150	40.0
1916	3.88	.47	1.72	13 608	24 701	21 725	73 810	11.2
Av.	3.49	3.34	2.85	15 436	19 065	17 627	63 395	33.2

The ten years with the highest number of degree-hours gave an average yield of 29.2 bushels, while the ten years with the lowest number gave a yield of 32.3 bushels. The four years with the highest number of degree-hours gave an average yield of 25.2 bushels, while the four years with the lowest number gave an average of 30 bushels. The relation between the number of degree-hours and the rainfall, and the yield on the continuous corn plot at the Experiment Station at Urbana, is shown by the data presented in Table 11.

TABLE 11.—RELATION BETWEEN DEGREE-HOURS, RAINFALL, AND YIELD OF CONTINUOUS CORN PLOT, AGRICULTURAL EXPERIMENT STATION, URBANA

Degree-hours	Average yield of corn per acre	Average rainfall for July and August
	bushels	*inches*
Over 70,000	21.0 for 4 years	3.30
Between 70,000 and 65,000	32.6 for 5 years	6.05
Between 65,000 and 60,000	36.5 for 8 years	6.87
Below 60,000	36.6 for 11 years	6.82

These data indicate that altho a lower yield occurs during the years of higher temperature, the higher temperature may be correlated with low rainfall, the consequent lack of moisture preventing the crop from utilizing the temperature possibilities.

EXTREME NORTHERN DISTRICT

The average temperature for the six northern counties that comprize the extreme northern district is 47.2 degrees. The average for winter is 21.8 degrees; for spring, 46.4 degrees; for summer, 70.4 degrees, and for fall, 50.3 degrees. The lowest temperature reached at any place in the district was -31 degrees at Riley in 1884, and the maximum was 110 degrees at Winnebago in 1901, a range of 141 degrees. The greatest range recorded for any one place is 138 degrees for Riley, in McHenry county. The same range occurred at Dubuque, Iowa, just across the Mississippi river, altho the minimum there reached -32 degrees. The average yearly range by monthly averages is 53.7 degrees.

The average annual maximum temperature for this district is 96.1 degrees, and the average minimum is -17.3 degrees, a range of 113.4 degrees. The average annual temperature has varied from 43.2 degrees in 1885 to 49.8 degrees in 1878, a range of 6.6 degrees (see Appendix, page 121). At Riley, in McHenry county, twenty-four winters since 1870 have had temperatures of -20 degrees or lower, while every winter with the exception of 1906, 1911, and 1913 has reached at least as low as -10 degrees. This station is a fair representative of those of the district.

TABLE 12.—AVERAGE SEASONAL TEMPERATURES: 1876 TO 1915

District	Winter	Spring	Summer	Autumn
Extreme northern	21.8	46.4	70.4	50.3
Central-northern	24.7	48.3	71.8	51.9
Central	28.8	51.9	74.2	54.7
Central-southern	33.1	55.0	76.1	57.2
Extreme southern	37.0	57.8	77.4	59.6

TABLE 13.—AVERAGE MONTHLY MAXIMUM AND MINIMUM TEMPERATURES OF THE VARIOUS DISTRICTS OF THE STATE: 1876 TO 1915

Month		Extreme northern	Central-northern	Central	Central-southern	Extreme southern
January	Max.	47	52	57	63	65
	Min.	-14	—9	—5	0	4
February	Max.	50	54	60	64	68
	Min.	-10	—8	—4	—1	5
March	Max.	64	67	72	75	77
	Min.	5	8	12	16	20
April	Max.	79	82	83	84	84
	Min.	22	23	26	28	30
May	Max.	86	88	89	91	90
	Min.	33	34	36	38	42
June	Max.	92	94	94	96	94
	Min.	43	43	46	49	54
July	Max.	95	97	98	99	97
	Min.	50	50	52	55	59
August	Max.	93	95	96	99	97
	Min.	48	48	51	53	56
September	Max.	89	92	93	95	94
	Min.	35	37	39	40	44
October	Max.	80	83	84	86	86
	Min.	24	25	27	28	32
November	Max.	66	69	72	75	76
	Min.	10	12	14	17	20
December	Max.	51	54	58	62	64
	Min.	—5	—1	2	7	11
Average annual	Max.	74	77	80	82	83
	Min.	20	22	25	28	31

TABLE 14.—AVERAGE MONTHLY AND ANNUAL TEMPERATURE: EXTREME NORTHERN DISTRICT
10-, 20-, AND 40-YEAR PERIODS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1876–1885	18.0	24.2	31.9	46.8	59.0	67.0	72.5	70.1	62.2	53.2	34.9	23.1	46.9
1886–1895	16.6	20.9	31.5	48.1	57.6	69.4	73.1	70.3	62.7	49.2	34.1	26.2	46.6
1896–1905	20.7	18.3	34.1	48.0	60.1	67.6	73.1	70.8	63.4	52.8	37.2	23.1	47.4
1906–1915	21.3	22.9	34.5	48.0	58.0	67.6	72.5	70.6	64.2	51.5	38.5	25.8	48.0
1876–1895	17.3	22.6	31.7	47.5	58.3	68.2	72.8	70.2	62.5	51.2	34.5	24.7	46.8
1896–1915	21.0	20.6	34.3	48.0	59.0	67.6	72.8	70.7	63.8	52.2	37.9	24.5	47.7
1876–1915	19.1	21.6	33.0	47.7	58.7	67.9	72.8	70.5	63.1	51.7	36.2	24.6	47.2

TABLE 15.—MAXIMUM AND MINIMUM TEMPERATURES: EXTREME NORTHERN DISTRICT

County	Station	Length of record	Average annual maximum	Average annual minimum	Average daily maximum	Average daily minimum	Maximum for period		Minimum for period	
		years					*year*		*year*	
Jo Daviess	Dubuque, Iowa	40	96.3	–19.3	74.5	18.3	1901	106	1887	–32
Lake	Antioch	12	96.6	–15.5	72.1	18.2	1911	105	1904	–25
McHenry	Riley	44	94.7	–18.4	72.0	15.4	1901	107	1884	–31
Winnebago	Kishwaukee	17	96.4	–17.1	73.4	17.3	1901	108	1905	–26
Winnebago	Rockford	25	95.7	–16.6	73.4	16.7	1901	108	1885	–26
Winnebago	Winnebago	25	97.0	–17.0	73.5	17.3	1901	110	1905	–26
Average	....	..	96.1	–17.3	73.2	17.2	....	...	...	....

The average time of the last killing frost in spring is May 4, while the earliest one in fall is October 12, thus giving a growing season of 161 days.

CENTRAL-NORTHERN DISTRICT

The central-northern district is about 100 miles wide north and south and includes the northern half of the corn belt. The average temperature for the forty-year period from 1876 to 1915 is 49.2 degrees. The average winter temperature is 24.7 degrees; of spring, 48.3 degrees; of summer, 71.8 degrees; and of fall, 51.9 degrees. The lowest temperature recorded was -30 degrees in February, 1905, at Aledo, in Mercer county, and at Morrison, in Whiteside county, while the highest was 112 degrees at Ottawa in 1901. This gives a range of 142 degrees. The greatest range recorded for any one place is 138 degrees at Ottawa and at Aledo. The greatest yearly range by monthly averages is 52.0 degrees.

The average annual maximum temperature for the district is 97.4 degrees, and the annual minimum is -14.1 degrees. The lowest annual temperature was 45.7 degrees for 1885, while the highest was 52.1 degrees for 1878 (see Appendix, page 122).

Taking Ottawa, in LaSalle county, as about the center of the district, it will be fairly representative of the conditions of the district. During a record of twenty-nine years, sixteen summers have had a temperature at some time of 100 degrees or more; eight winters have had a temperature below -20 degrees; eleven, between -10 degrees and -20 degrees; and nine between zero and -10 degrees. In 1906 the lowest temperature was 3 degrees above zero.

The average dates for the latest and the earliest killing frosts are May 2 and October 15, giving an average growing season of 166 days.

CENTRAL DISTRICT

The width of the central district north and south is about 108 miles. The average temperature is 52.4 degrees, or 3.2 degrees warmer than the central-northern district. The average temperature for winter is 28.8 degrees; for spring, 51.9 degrees, for summer, 74.2 degrees; and for fall, 54.7 degrees. The lowest temperature recorded was -30 degrees at LaHarpe, in Hancock county, in 1905, and the highest was 111 degrees at Coatsburg, in Adams county, in 1901, giving a range of 141 degrees. The greatest range for any one place is 140 degrees at Coatsburg. The average yearly range by monthly averages is 49.6 degrees.

The average annual maximum temperature for the district is 98.1 degrees, and the average minimum is -11.1. The lowest annual temperature was 49.6 degrees for 1885, and the highest was 54.5 degrees

TABLE 16.—AVERAGE MONTHLY AND ANNUAL TEMPERATURE: CENTRAL-NORTHERN DISTRICT
10-, 20-, AND 40-YEAR PERIODS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1876–1885	21.9	27.9	35.2	48.3	58.8	67.9	73.9	72.0	63.9	52.7	38.7	26.8	49.0
1886–1895	19.8	24.4	34.5	50.0	58.9	70.9	74.3	71.5	64.4	50.5	35.9	29.0	48.6
1896–1905	23.2	20.8	36.5	49.3	61.7	69.3	74.4	72.1	64.8	54.1	39.0	25.6	49.2
1906–1915	24.1	25.5	36.6	49.8	59.9	69.2	74.0	72.2	65.6	52.9	40.3	27.6	49.8
1876–1895	20.9	26.2	34.9	49.2	58.9	69.4	74.1	71.8	64.2	51.6	37.3	27.9	48.9
1896–1915	23.7	23.2	36.6	49.6	60.8	69.3	74.2	72.2	65.2	53.5	39.7	26.6	49.6
1876–1915	22.2	24.7	35.7	49.4	59.8	69.3	74.2	71.9	64.7	52.6	38.5	27.3	49.2

TABLE 17.—MAXIMUM AND MINIMUM TEMPERATURES: CENTRAL-NORTHERN DISTRICT

County	Station	Length of record	Average annual maximum	Average annual minimum	Average daily maximum	Average daily minimum	Maximum for period		Minimum for period	
		years					year		year	
Bureau	Tiskilwa	17	97.5	–15.0	74.9	19.8	1901	108	1905	–28
Bureau	Walnut	21	98.5	–14.0	75.4	20.0	1901	108	1905	–26
Carroll	Lanark	22	97.3	–18.3	73.4	17.3	1887	104	1905	–29
Carroll	Zion	18	96.0	–17.7	72.8	18.2	1911	103	1905	–28
Cook	Chicago	41	94.6	–11.9	74.0	20.3	1901	103	1872	–23
Cook	LaGrange	18	97.3	–13.1	73.8	19.5	1901	104	1905	–22
DeKalb	Sycamore	29	96.9	–16.3	73.6	16.2	1911	106	1884	–28
Henry	Galva	20	98.3	–14.7	75.2	18.7	1901	108	1905	–28
Iroquois	Martinton	17	98.7	–12.6	75.1	22.2	1901	106	1905	–23
Kane	Aurora	26	97.7	–15.5	73.7	18.1	1901	109	1905	–25

TABLE 17.—*Concluded*

County	Station	Length of record	Average annual maximum	Average annual minimum	Average daily maximum	Average daily minimum	Maximum for period		Minimum for period	
Kane	Elgin	7	96.3	–12.1	74.1	17.6	1911	101	1899	–23
Kane	St. Charles	16	96.8	–15.8	75.0	26.5	1901	106	1905	–24
Kendall	Yorkville	13	98.7	–15.5	74.4	18.4	1901	106	1905	–26
LaSalle	LaSalle	10	96.7	–10.0	74.8	21.2	1903 1911	101	1905	–24
LaSalle	Ottawa	26	99.3	–13.5	76.4	20.5	1901	112	1887	–26
LaSalle	Streator	18	98.2	–12.0	75.6	20.8	1901	107	1895	–25
Lee	Dixon	21	97.9	–14.0	74.6	18.2	1901	108	1905	–27
Livingston	Dwight	18	98.7	–11.3	75.9	22.0	1911	105	1899	–22
Livingston	Pontiac	15	99.1	–10.5	75.9	22.9	1911	106	1887	–26
Marshall	Henry	15	97.9	–12.6	75.5	24.1	1901	111	1905	–27
Mercer	Aledo	15	97.0	–14.4	74.6	18.6	1901	108	1905	–30
Ogle	Oregon	7	98.6	–23.4	75.5	16.6	1894	106	1895	–26
Peoria	Peoria	57	99.0	–11.7	77.9	21.2	1887 1901	106	1884	–27
Rock Island	Davenport, Ia.	40	95.6	–14.6	74.6	18.7	1911	104	1884	–27
Warren	Monmouth	20	99.9	–15.0	75.6	20.4	1901	107	1905	–27
Whiteside	Morrison	10	95.1	–15.5	72.8	18.7	1911	105	1905	–30
Will	Joliet	20	97.5	–11.9	74.6	18.9	1901	104	1905	–23
Woodford	Minonk	18	98.7	–12.8	75.9	21.0	1901	106	1905	–28
Average	....	..	97.4	–14.1	74.8	19.9	....	...	....	...

TABLE 18.—AVERAGE MONTHLY AND ANNUAL TEMPERATURE: CENTRAL DISTRICT
10–, 20–, AND 40–YEAR PERIODS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1876–1885	26.6	32.9	39.5	52.9	62.3	71.0	76.8	74.4	66.4	55.7	40.9	29.5	52.4
1886–1895	24.6	29.0	38.6	53.6	62.2	73.1	76.1	73.8	66.9	53.1	39.4	32.6	51.9
1896–1905	27.2	25.3	40.8	52.4	64.4	71.8	76.3	74.7	67.4	57.0	42.3	29.4	52.4
1906–1915	28.8	29.5	40.3	53.2	62.9	71.9	76.3	74.5	68.2	55.3	43.4	31.1	52.9
1876–1895	25.6	31.0	39.1	53.3	62.3	72.1	76.5	74.1	66.7	54.4	40.2	31.1	52.2
1896–1915	28.0	27.4	40.6	52.8	63.7	71.9	76.3	74.6	67.8	56.2	42.9	30.3	52.7
1876–1915	26.8	29.2	39.8	53.0	62.9	71.9	76.4	74.4	67.2	55.3	41.5	30.4	52.4

TABLE 19.—MAXIMUM AND MINIMUM TEMPERATURES: CENTRAL DISTRICT

County	Station	Length of record	Average annual maximum	Average annual minimum	Average daily maximum	Average daily minimum	Maximum for period		Minimum for period	
		years					*year*		*year*	
Adams	Coatsburg	17	98.1	–11.3	77.4	23.5	1901	111	1905	–29
Champaign	Philo	26	97.8	–14.6	75.4	22.4	1887	108	1887	–27
Champaign	Rantoul	21	98.7	–13.7	76.1	21.9	1901	106	1894 1905	–24
Champaign	Urbana	25	96.3	–13.0	74.7	22.4	1901	104	1899 1905	–25
Christian	Morrisonville	17	97.0	–13.0	76.2	25.9	1901	110	1899	–29
Christian	Pana	22	97.5	–10.6	80.9	25.3	1901	107	1912	–25
Clark	Martinsville	25	97.5	– 8.6	....	....	1909	102	1887 1904 1905	–22
Coles	Charleston	23	97.5	–11.0	76.8	25.3	1887	107	1905	–23
Douglas	Tuscola	19	98.3	–11.6	76.3	24.8	1901	110	1899	–21
Edgar	Paris	22	98.7	– 9.5	76.7	24.8	1897	107	1905	–21

TABLE 17.—*Concluded*

County	Station	Length of record	Average annual maximum	Average annual minimum	Average daily maximum	Average daily minimum	Maximum for period		Minimum for period	
Kane	Elgin	7	96.3	–12.1	74.1	17.6	1911	101	1899	–23
Kane	St. Charles	16	96.8	–15.8	75.0	26.5	1901	106	1905	–24
Kendall	Yorkville	13	98.7	–15.5	74.4	18.4	1901	106	1905	–26
LaSalle	LaSalle	10	96.7	–10.0	74.8	21.2	1903 1911	101	1905	–24
LaSalle	Ottawa	26	99.3	–13.5	76.4	20.5	1901	112	1887	–26
LaSalle	Streator	18	98.2	–12.0	75.6	20.8	1901	107	1895	–25
Lee	Dixon	21	97.9	–14.0	74.6	18.2	1901	108	1905	–27
Livingston	Dwight	18	98.7	–11.3	75.9	22.0	1911	105	1899	–22
Livingston	Pontiac	15	99.1	–10.5	75.9	22.9	1911	106	1887	–26
Marshall	Henry	15	97.9	–12.6	75.5	24.1	1901	111	1905	–27
Mercer	Aledo	15	97.0	–14.4	74.6	18.6	1901	108	1905	–30
Ogle	Oregon	7	98.6	–23.4	75.5	16.6	1894	106	1895	–26
Peoria	Peoria	57	99.0	–11.7	77.9	21.2	1887 1901	106	1884	–27
Rock Island	Davenport, Ia.	40	95.6	–14.6	74.6	18.7	1911	104	1884	–27
Warren	Monmouth	20	99.9	–15.0	75.6	20.4	1901	107	1905	–27
Whiteside	Morrison	10	95.1	–15.5	72.8	18.7	1911	105	1905	–30
Will	Joliet	20	97.5	–11.9	74.6	18.9	1901	104	1905	–23
Woodford	Minonk	18	98.7	–12.8	75.9	21.0	1901	106	1905	–28
Average	....	..	97.4	–14.1	74.8	19.9	....	...	....	...

TABLE 18.—AVERAGE MONTHLY AND ANNUAL TEMPERATURE: CENTRAL DISTRICT
10-, 20-, AND 40-YEAR PERIODS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1876–1885	26.6	32.9	39.5	52.9	62.3	71.0	76.8	74.4	66.4	55.7	40.9	29.5	52.4
1886–1895	24.6	29.0	38.6	53.6	62.2	73.1	76.1	73.8	66.9	53.1	39.4	32.6	51.9
1896–1905	27.2	25.3	40.8	52.4	64.4	71.8	76.3	74.7	67.4	57.0	42.3	29.4	52.4
1906–1915	28.8	29.5	40.3	53.2	62.9	71.9	76.3	74.5	68.2	55.3	43.4	31.1	52.9
1876–1895	25.6	31.0	39.1	53.3	62.3	72.1	76.5	74.1	66.7	54.4	40.2	31.1	52.2
1896–1915	28.0	27.4	40.6	52.8	63.7	71.9	76.3	74.6	67.8	56.2	42.9	30.3	52.7
1876–1915	26.8	29.2	39.8	53.0	62.9	71.9	76.4	74.4	67.2	55.3	41.5	30.4	52.4

TABLE 19.—MAXIMUM AND MINIMUM TEMPERATURES: CENTRAL DISTRICT

County	Station	Length of record	Average annual maximum	Average annual minimum	Average daily maximum	Average daily minimum	Maximum for period		Minimum for period	
		years					*year*		*year*	
Adams	Coatsburg	17	98.1	–11.3	77.4	23.5	1901	111	1905	–29
Champaign	Philo	26	97.8	–14.6	75.4	22.4	1887	108	1887	–27
Champaign	Rantoul	21	98.7	–13.7	76.1	21.9	1901	106	1894 1905	–24
Champaign	Urbana	25	96.3	–13.0	74.7	22.4	1901	104	1899 1905	–25
Christian	Morrisonville	17	97.0	–13.0	76.2	25.9	1901	110	1899	–29
Christian	Pana	22	97.5	–10.6	80.9	25.3	1901	107	1912	–25
Clark	Martinsville	25	97.5	– 8.6	....	....	1909	102	1887 1904 1905	–22
Coles	Charleston	23	97.5	–11.0	76.8	25.3	1887	107	1905	–23
Douglas	Tuscola	19	98.3	–11.6	76.3	24.8	1901	110	1899	–21
Edgar	Paris	22	98.7	– 9.5	76.7	24.8	1897	107	1905	–21

TABLE 19.—*Concluded*

County	Station	Length of record	Average annual maximum	Average annual minimum	Average daily maximum	Average daily minimum	Maximum for period		Minimum for period	
Fulton	Astoria	13	96.0	–11.0	74.6	23.4	1901	108	1905	–27
Greene	White Hall	12	96.9	– 9.4	77.1	25.0	1911	104	1912	–26
Hancock	Keokuk, Iowa	40	97.0	–13.0	76.9	22.5	1901	108	1905	–27
Hancock	LaHarpe	18	98.7	–14.4	76.4	22.0	1901	108	1905	–30
Logan	Lincoln	7	97.0	– 6.6	76.3	26.0	1908	99	1912	–22
Macon	Decatur	20	98.6	–13.0	76.4	24.2	1901	109	1905	–25
Macoupin	Carlinville	21	104.0	–11.0	77.4	26.1	1911	104	1905	–23
McLean	Bloomington	21	99.9	–11.8	76.5	22.3	1901	108	1895 1905	–24
Mason	Havana	21	99.0	– 9.5	77.9	24.5	1901	109	1905	–26
Montgomery	Hillsboro	18	100.0	– 8.8	77.5	26.8	1901	109	1905	–22
Morgan	Alexander	18	98.8	–12.0	77.0	24.8	1901	109	1905	–27
Moultrie	Sullivan	14	98.7	–10.7	78.5	24.1	1911	104	1905	–24
Piatt	Bement	5	98.8	– 8.8	76.6	24.7	1911	103	1912	–18
Pike	Griggsville	26	98.8	–10.0	76.5	24.4	1901	110	1887 1905	–25
Pike	Hannibal, Mo.	21	97.0	– 9.7	76.6	23.9	1911	104	1905	–25
Sangamon	Springfield	34	96.9	– 9.9	76.6	23.9	1901	107	1905	–24
Schuyler	Rushville	20	97.7	– 9.4	76.2	24.2	1890	106	1905	–26
Shelby	Windsor	13	98.0	–13.8	76.4	24.3	1911	104	1912	–25
Vermilion	Danville	10	99.0	– 9.8	76.2	23.7	1901	104	1912	–22
Vermilion	Hoopeston	11	96.1	–14.0	75.1	22.6	1911	103	1905	–25
Average	....	..	98.1	–11.1	76.7	24.1	....	...	....	...

for 1878 and again for 1913 (see Appendix, page 123). At Springfield during thirty-four years, sixteen winters have had temperatures of -10 degrees or lower, and in only one winter was the lowest temperature above zero. The lowest temperature recorded was -24 degrees in 1905. The coldest day of the year occurred in January during seventeen years, in February during twelve years, and in December five years.[1] The maximum summer temperature varies from 91 degrees to 107 degrees. Eight summers since 1880 have reached a temperature of 100 degrees or higher.

The average dates for the latest and the earliest killing frosts in spring and fall are April 26 and October 16, giving an average growing season of 173 days.

CENTRAL-SOUTHERN DISTRICT

The approximate average width of the central-southern district north and south is 105 miles. The average temperature is 55.3 degrees, or 2.9 degrees warmer than the central district. The average temperature for winter is 33.1 degrees, for spring, 55.0 degrees; for summer, 76.1 degrees; and for fall, 57.2 degrees. The lowest temperature recorded was -29 degrees at Montrose,[2] in Effingham county, in 1915, while the highest was 113 degrees at Greenville, in Bond county, in 1901, giving a range of 142 degrees. The greatest range for any one place is 134 degrees at Greenville. The greatest yearly range by monthly averages is 46.7 degrees.

The average annual maximum temperature for this district is 99.8 degrees, and the average minimum is -7.1 degrees, a range of 106.9 degrees. The lowest annual temperature was 52.9 degrees for 1885, while the highest was 57.6 degrees for 1908, giving a range of 4.7 degrees (see Appendix, page 124).

At McLeansboro, during twenty-six years, sixteen summers have reached a temperature of 100 degrees or above, the highest being 110 degrees. The lowest winter temperatures were -10 degrees or lower during ten winters, between zero and -10 degrees during nine winters, and above zero during seven winters. The lowest temperature was -19 degrees, and the range for the district 129 degrees.

The average dates of killing frosts in spring and fall are April 15 and October 20, giving an average growing season of 188 days.

EXTREME SOUTHERN DISTRICT

The extreme southern district includes the seven southern counties and is approximately 42 miles from north to south. The Ozark Ridge extends east and west across the northern part of the district. The highest point in southern Illinois, 1,046 feet above sea level in the northwest part of Pope county, is on this ridge.

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[1] In this respect, Springfield is fairly representative of the state as a whole.

[2] Records at Montrose have been kept only for the years 1912–1915.

TABLE 20.—AVERAGE MONTHLY AND ANNUAL TEMPERATURE: CENTRAL-SOUTHERN DISTRICT
10-, 20-, AND 40-YEAR PERIODS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1876–1885........	30.7	35.5	43.2	56.7	65.3	73.5	78.2	76.0	68.8	58.2	43.8	34.2	55.3
1886–1895........	28.9	33.5	42.0	56.3	64.2	74.9	77.6	75.3	68.7	54.9	42.6	36.2	54.5
1896–1905........	31.8	30.3	44.9	54.9	66.7	74.0	78.1	76.8	70.0	58.3	45.3	33.2	55.2
1906–1915........	33.8	33.8	44.7	55.7	65.5	74.1	78.1	76.7	71.1	57.9	46.5	35.1	56.2
1876–1895........	29.8	34.5	42.6	56.5	64.8	74.2	77.9	75.7	68.8	56.6	43.2	35.2	54.9
1896–1915........	32.8	32.1	44.8	55.3	66.1	74.1	78.1	76.8	70.6	58.1	45.9	34.2	55.7
1876–1915........	31.3	33.3	43.7	55.9	65.2	74.1	78.0	76.2	69.7	57.3	44.6	34.7	55.3

TABLE 21.—MAXIMUM AND MINIMUM TEMPERATURES: CENTRAL-SOUTHERN DISTRICT

County	Station	Length of record	Average annual maximum	Average annual minimum	Average daily maximum	Average daily minimum	Maximum for period		Minimum for period	
		years					*year*		*year*	
Bond	Greenville	26	99.0	− 6.6	77.7	24.1	1901	113	1905	−21
Clay	Flora	17	99.0	−10.0	77.4	26.0	1901	108	1904	−25
Crawford	Palestine	25	98.6	− 8.0	77.3	27.5	1887	105	1899	−21
Crawford	Robinson	16	97.6	− 6.6	76.8	27.4	1901	108	1899	−20
Edwards	Albion	20	100.0	− 7.0	77.4	28.6	1901	109	1899	−21
Gallatin	Equality	15	101.0	− 5.8	79.9	31.7	1909	105	1899	−22
Hamilton	McLeansboro	23	101.0	− 5.6	78.5	29.8	1911	105	1899 1912	−19
Jefferson	Mt. Vernon	18	101.0	− 5.0	....	....	1901	112	1899	−22
Lawrence	Sumner	5	100.0	− 8.8	78.4	29.7	1887	108	1910	−21
Perry	DuQuoin	6	102.0	− 7.0	79.3	30.4	1888 1911	105	1912	−22
Randolph	Sparta	15	99.8	− 8.3	78.3	29.2	1911	105	1912	−19
Richland	Olney	25	99.0	− 7.0	78.3	28.7	1893	110	1912	−21
St. Clair	Mascoutah	25	100.0	− 8.3	78.5	27.5	1901	109	1899 1904	−20
St. Clair	St. Louis, Mo.	60	100.0	− 3.6	79.5	28.2	1850	102	1864	−20
Wayne	Fairfield	8	98.7	− 8.6	80.3	30.3	1887	108	1912	−18
Average	....	..	99.8	−7.1	78.4	28.5	....	...	....	...

TABLE 22.—AVERAGE MONTHLY AND ANNUAL TEMPERATURE: EXTREME SOUTHERN DISTRICT
10–, 20–, AND 40–YEAR PERIODS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1876–1885........	35.9	41.2	47.5	59.1	67.7	75.1	79.4	77.3	69.8	60.9	46.9	38.1	58.2
1886–1895........	33.8	38.1	46.1	59.6	66.3	75.5	78.5	76.8	70.7	57.6	45.8	40.1	57.4
1896–1905........	35.6	34.0	48.4	57.6	69.3	75.9	79.9	79.1	72.5	61.0	48.6	36.7	58.2
1906–1915........	36.6	36.7	47.1	57.5	66.8	75.2	78.9	77.4	72.5	59.6	48.8	37.4	57.8
1876–1895........	34.9	39.7	46.8	59.4	67.0	75.3	79.0	77.1	70.1	59.3	46.4	39.1	57.8
1896–1915........	36.2	35.4	47.8	57.6	68.1	75.6	79.4	78.3	72.5	60.3	48.7	37.1	58.1
1876–1915........	35.5	37.5	47.3	58.4	67.5	75.4	79.2	77.6	71.4	59.8	47.5	38.1	57.9

TABLE 23.—MAXIMUM AND MINIMUM TEMPERATURES: EXTREME SOUTHERN DISTRICT

County	Station	Length of record	Average annual maximum	Average annual minimum	Average daily maximum	Average daily minimum	Maximum for period		Minimum for period	
		years					*year*		*year*	
Alexander........	Cairo............	32	96.0	– 8.0	79.0	33.0	1901	106	1899	–14
Johnson..........	New Burnside......	18	100.3	– 6.6	79.3	31.5	1897 1899	104	1912	–26
Pope............	Golconda..........	16	98.7	– 1.0	79.1	30.8	1909	104	1912	–16
Union...........	Cobden...........	17	101.0	– 5.3	79.3	32.5	1899 1900	105	1899	–19
Average.......	....	..	99.0	– 5.2	79.2	32.0	...	....	....	...

The average temperature for the district is 57.9 degrees, which is 10.7 degrees higher than the average for the extreme northern district. The average temperature for the winter months is 37 degrees; for spring, 57.8 degrees; for summer, 77.4 degrees; and for fall, 59.6 degrees. These temperatures are higher than those of the extreme northern district by 15.2 degrees in winter, 11.4 degrees in spring, 7.0 degrees in summer, and 9.3 degrees in the fall. The lowest recorded temperature was -26 degrees at New Burnside, in Johnson county, in 1912, while the highest was 106 degrees at Cairo in 1901, a range of 132 degrees. The greatest recorded range in any one place is 130 degrees at New Burnside. The greatest yearly range by monthly averages is 43.7 degrees.

The average annual maximum temperature for the district is 99.0 degrees, and the minimum -5.2 degrees, a range of 104.2 degrees. The lowest annual temperature was 55.4 degrees for 1886, and the highest was 59.8 degrees for 1900 (see Appendix, page 125).

The average dates for the latest and the earliest killing frosts in spring and fall are April 14 and October 24, thus giving a growing season of 193 days. This is thirty-two days longer than the growing season of the extreme northern district.

The average daily maximum temperature is 18 degrees higher in the extreme southern than in the extreme northern district, for January and February, but only 2 degrees higher for July and 4 degrees for August.

TEMPERATURE OF SOIL

The temperature of the soil is a very important factor, not only in plant growth as usually manifest, but also in the biological activities taking place in the soil, by which nitrification proceeds. It is dependent upon: (1) the moisture content of the soil, (2) the color, (3) the compactness, (4) the vegetative covering, and (5) the inclination of the surface of the soil to the sun's rays. It is not necessary to discuss each of these factors separately, and further, it would be difficult to say which is of the greatest importance. Under varying conditions each may in turn be the factor of greatest influence.

The average monthly temperature of the soil to a depth of 1 to 3 inches is always higher than that of the air above it.

Table 24 shows the annual maximum and minimum temperatures of soil at various depths as recorded for sixteen years at this station. It will be noted that in only three winters out of the sixteen recorded did the temperature of the soil at a depth of 12 inches fail to reach as low as 32 degrees, or the freezing point. From this fact it is evident that during most winters the soil freezes deeper than 12 inches.

TABLE 24.—MAXIMUM AND MINIMUM TEMPERATURES OF AIR, AND OF SOIL AT DIFFERENT DEPTHS
ILLINOIS AGRICULTURAL EXPERIMENT STATION AT URBANA

Year	Air		1 inch		3 inches		6 inches		9 inches		12 inches		24 inches		36 inches	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1901	104	−15	108	8	97	16	86.5	32	83.5	32	80	32	....	....	71	37.5
1902	92	−14	103	6	95	22	85.5	30	82.5	32	78.5	32.5	....	....	70	37
1903	96	−17	89.5	16	89	18	89	24	79	29	76.5	31.5	....	....	68.5	39
1904	92	−15	88	15	82	....	78	22	77	25	75	28	....	....	66	36.5
1905	97	−24.5	95	5	87	11	81	15	79.5	....	76	23	....	....	68	35
1906	94	− 7	99	....	92	....	83	28	78	28	....	32	....	....	69	38.5
1907	93	− 3	91	19	84	23	79.5	30	77.5	31	75.5	32.5	....	....	67.5	39
1908	94	− 2	91	20.5	88	23.5	....	28.5	....	30	78	31.5	....	....	67	38
1909	94	−13	91	21	85	22	80	....	79	28	77	33	....	....	69.5	39.5
1910	95	−12	99	18	90	18	85	20	83	27	76.5	30	....	....	67	38
1911	102	0	100	20	97	21	88	25	85	27	80	31	....	....	69	39.5
1912	95	−22.5	90	15	86	17	81	21	79	25	78	27	71	....	69	36
1913	103	− 9	96.5	23	95	22	....	23	....	27	79.5	30	71	36	69.5	38
1914	99	−13	96	27.5	93.5	27.5	....	....	....	....	77.5	31.5	71.5	35.5	69	37.5
1915	90	−15	85.5	23	85	23.5	....	....	....	....	76	29	70	35.5	67	38
1916	101	− 9	99.5	19.5	100	19	85.5	....	....	....	79	28.5	74	36	70.5	38
Average	96	−12	95.1	17.1	90.3	20.2	83.5	24.9	80.3	28.4	77.5	30.2	71.5	35.7	68.6	37.8

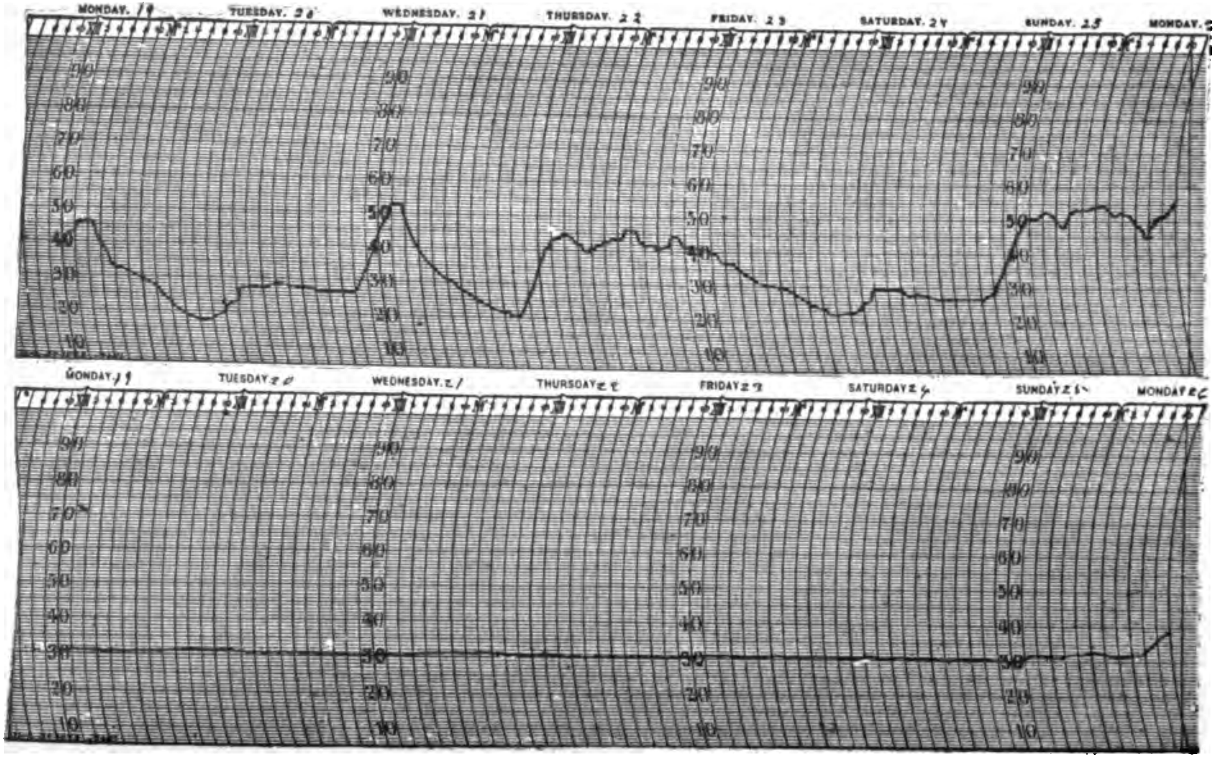

FIG. 13.—UPPER GRAPH: RECORD OF AIR TEMPERATURE MADE BY RECORDING THERMOMETER (THERMOGRAPH) FROM NOON, FEBRUARY 19, TO NOON, FEBRUARY 26, 1917. LOWER GRAPH: RECORD OF TEMPERATURE OF SOIL THREE INCHES DEEP MADE DURING THE SAME PERIOD

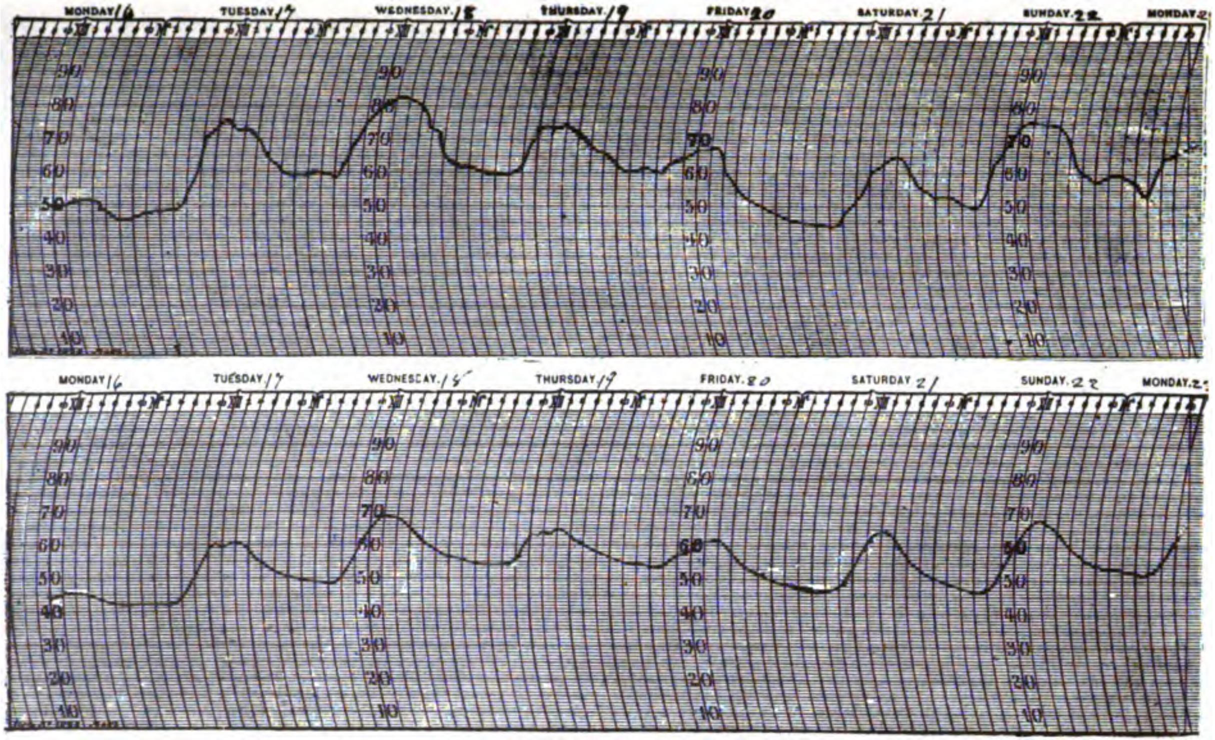

FIG. 14.—UPPER GRAPH: RECORD OF AIR TEMPERATURE MADE BY A RECORDING THERMOMETER (THERMOGRAPH) FROM NOON, APRIL 16, TO NOON, APRIL 23, 1917. LOWER GRAPH: RECORD OF TEMPERATURE OF SOIL THREE INCHES DEEP DURING THE SAME PERIOD

The lowest temperature for the 12-inch depth was 23 degrees in 1905. The 24-inch thermometer was not used until 1912, but since that time the lowest temperature recorded at that depth was 35.5 degrees; which fact would indicate that frost reaches but little beyond the 12-inch depth. The winter having the deepest frost penetration was in 1905, when the lowest temperature recorded by the 36-inch thermometer was 35 degrees, and of the 12-inch thermometer 23 degrees. (In February, 1917, the 24-inch thermometer reached 32 degrees, and the 12-inch 24.5 degrees. The soil, therefore, must have frozen to a depth of 24 inches at least, from which it is evident that in 1905 the frost must have penetrated to an even greater depth.)

Table 25 gives the temperature of soil at different depths by monthly averages.

TABLE 25.—AVERAGE MONTHLY TEMPERATURE OF SOIL AT DIFFERENT DEPTHS
ILLINOIS AGRICULTURAL EXPERIMENT STATION, URBANA
(The average air temperature of the same place is given for comparison)

Depth	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Ten-Year Average: 1897-1906												
Air	26.2[9]	22.6[9]	37.3[9]	49.5[9]	62.6[9]	70.0[9]	74.7	72.8	66.0	54.8	39.8	27.7
1 inch	26.9[7]	27.3[8]	40.1[6]	51.1[7]	64.1[7]	73.3[8]	79.4[9]	76.6[9]	70.1[9]	56.4[9]	41.1[9]	30.2[8]
3 inches	30.5[7]	29.5[6]	39.6[7]	50.2[8]	62.5[7]	72.8[8]	78.5[9]	76.4[9]	69.7[9]	57.9[9]	42.3[9]	32.3[8]
6 inches	32.6[7]	30.7[8]	38.7[8]	49.2[8]	61.8[7]	70.9[8]	76.8[9]	75.5[9]	69.8[9]	58.3[9]	44.1[9]	34.7[8]
9 inches	33.2[7]	33.2[6]	39.2[7]	48.7[7]	60.7[6]	70.4[8]	75.8[9]	75.2[8]	69.3[8]	58.8[8]	45.8[8]	35.8[8]
12 inches	34.0[7]	33.1[6]	38.8[7]	48.2[7]	59.3[6]	68.1[7]	74.5[8]	73.7[7]	68.6[7]	59.0[8]	46.5[8]	37.0[8]
36 inches	40.9[7]	38.3[7]	40.0[7]	45.8[7]	54.3[8]	61.1[8]	66.3[9]	68.0[8]	66.4[8]	61.3[8]	53.6[8]	45.5[8]
Ten-Year Average: 1907-1916												
Air	27.6	28.1	39.2	50.8	62.3	71.3	76.3	73.8	66.2	54.1	42.0	29.5
1 inch	31.5	31.7	39.6	51.0	62.0	72.0	77.0	75.9	68.0	54.6	43.3	34.0
3 inches	31.6	31.8	39.4	51.0	61.8	71.7	77.1	75.3	68.2	55.7	43.7	34.5
6 inches	32.7[7]	32.3[7]	39.9[6]	49.3[6]	59.3[7]	70.1[6]	74.9[6]	74.1[6]	67.9[6]	55.7[5]	43.8[6]	35.2[7]
9 inches	33.3[7]	32.9[6]	39.3[5]	48.8[5]	59.0[5]	68.5[5]	73.6[5]	72.9[6]	68.0[5]	56.1[5]	44.5[6]	36.3[7]
12 inches	33.9	33.3	38.4	48.7	58.4	67.8	73.0	72.6	67.9	57.0	45.9	37.8
24 inches[4]	37.6	37.1	38.6	47.1	55.4	62.6	68.5	69.7	66.7	59.5	50.6	42.7
36 inches	41.2	39.2	40.2	46.3	53.0	59.5	65.8	67.7	65.8	60.1	52.5	46.0

[4] Four-year average.
[5] Five-year average.
[6] Six-year average.
[7] Seven-year average.
[8] Eight-year average.
[9] Nine-year average.

FROST

The times of killing frosts in spring and autumn are very important, as they determine the length of the growing season. From data collected it has been found that the average date of the last killing frost in spring and the first in autumn, for each district in the state, is as recorded in Table 26.

The growing season is nearly two weeks longer in the central than in the extreme northern district, while in the extreme southern district it is nearly three weeks longer than in the central. The average length of the growing season for the northern tier of counties is 161 days, while that of the seven southern counties is 193 days, or nearly five weeks longer. Observations in cities of some size show that the last killing frost in spring is earlier and the first in fall later than in country districts.

TABLE 26.—AVERAGE DATE OF KILLING FROSTS IN ILLINOIS

District	Last in spring	First in autumn	Number of days in growing season
Extreme northern................	May 4	October 12	161
Central-northern.................	May 2	October 15	166
Central..........................	April 26	October 16	173
Central-southern.................	April 15	October 20	188
Extreme southern................	April 14	October 24	193

The latest killing frosts in spring recorded for northern Illinois were on June 9, 1901, in Winnebago and Carroll counties; on May 27, 1915, at Dakota in Stephenson county; and on May 31, 1897, over this district generally. The earliest killing frosts in fall were reported at Dakota, August 30, 1915, and at Lanark, September 12, 1902. The earliest general killing frost for this section was on September 18, 1901.

In central Illinois the latest killing frost in spring was recorded at Philo, Champaign county, on May 31, 1897, while Springfield recorded one on May 29, 1882. A somewhat general killing frost occurred on May 24, 1892. The earliest killing frost in fall for this section was recorded at Springfield on September 13, 1890, and one of rather general occurrence was recorded on September 18, 1901.

For southern Illinois the latest killing frost in the spring was on May 31, 1894, while the latest general one at this season was on May 14, 1895. The earliest in fall was on September 14, in 1902, while a general one occurred on September 30, 1899,

WIND

Illinois lies in the belt of the prevailing westerly winds, in which the general atmospheric movement is from west to east; yet the presence of the cyclones and anticyclones causes great variation both in direction and in velocity.

DIRECTION

In Table 27 is shown the wind direction as determined for seasons rather than for months. The effect of Lake Michigan in modifying the direction of the wind places a small area of northeastern Illinois in a region by itself, which may be designated as the lake-breeze area. In this section the wind blows from the northeast during 40.8 percent of the time in the spring and 37.5 percent of the time in the summer months, while during the fall and winter months it blows from the west and the south.

TABLE 27.—TIME DURING WHICH WIND BLOWS FROM DIRECTION INDICATED
(Expressed in percentage)

District	N	NW	W	SW	S	SE	E	NE
Winter: December, January, and February								
Extreme northern......	1.4	56.3	18.2	15.8	7.3	.7	.0	.3
Central-northern.......	1.3	47.0	19.6	24.2	3.6	1.5	.3	2.5
Central...............	2.7	46.8	10.0	18.4	13.9	5.5	1.2	1.6
Central-southern........	11.3	37.6	9.3	14.1	18.4	6.0	.4	2.9
Extreme southern......	36.5	11.8	4.7	5.9	32.9	4.6	.0	3.6
Spring: March, April, and May								
Extreme northern......	4.9	41.3	5.3	14.6	14.7	8.1	5.3	5.8
Central-northern.......	5.2	23.0	5.8	29.5	7.4	9.1	5.8	14.2
Central...............	4.6	25.4	5.0	18.0	19.7	15.6	5.1	6.6
Central-southern........	6.4	17.2	6.9	18.2	30.1	12.7	1.8	6.7
Extreme southern......	13.1	6.5	1.3	5.7	65.0	2.0	1.4	5.0
Summer: June, July, and August								
Extreme northern......	4.0	17.5	4.3	33.6	19.4	12.2	2.7	6.3
Central-northern.......	1.8	9.7	1.7	42.9	10.5	10.3	9.3	13.8
Central...............	2.0	6.8	4.0	43.4	20.7	11.1	4.4	7.6
Central-southern........	2.8	2.5	4.1	38.5	32.0	10.4	3.1	6.6
Extreme southern......	4.6	.4	1.3	14.9	67.4	2.8	4.5	4.1
Autumn: September, October, and November								
Extreme northern......	3.3	25.4	5.9	36.6	21.4	6.4	.0	1.0
Central-northern.......	.7	17.9	8.0	41.3	18.3	8.9	2.0	2.9
Central...............	2.5	17.5	6.2	31.0	23.9	14.3	1.7	2.9
Central-southern........	8.3	17.4	4.2	25.5	27.7	9.8	1.8	5.3
Extreme southern......	20.3	7.8	3.0	3.1	53.2	3.3	4.7	4.6
Average for Year								
Extreme northern......	3.4	35.1	8.4	25.2	15.7	6.9	2.0	3.3
Central-northern.......	2.3	24.4	8.8	34.5	9.9	7.4	4.3	8.4
Central...............	2.9	24.2	6.3	27.7	19.5	11.6	3.1	4.7
Central-southern........	7.2	18.7	6.1	24.1	27.1	9.7	1.8	5.3
Extreme southern......	18.6	6.6	2.6	7.4	54.6	3.2	2.7	4.3

VELOCITY OF AIR MOVEMENT

The data regarding wind velocity have been obtained from the published records of the stations of the Weather Bureau within the state and the five along the Mississippi river. The anemometer, the regular Weather Bureau instrument, is used for determining the velocity of the air movement, but comparisons of the data of the various stations are very unsatisfactory because of the varying heights of the instruments above the ground or above the buildings surrounding them. They vary in height from 70 feet to over 200 feet above the ground.

The velocity of the wind is greatest during November, December, January, February, March, and April, when the average hourly velocity is 10.4 miles; while May, June, July, August, September, and October have the least atmospheric movement, 8.0 miles per hour. March and April are the windiest months, while July and August have the least wind movement. The season of greatest wind velocity is very significant to the farmer because of the resulting increased evaporation. Table 28 gives the velocity for the three divisions of the state.

TABLE 28.—VELOCITY OF AIR MOVEMENT
(Miles per hour)

Division	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Aver.
Northern..	9.9	10.4	10.9	11.1	9.8	8.2	7.7	7.1	8.4	9.1	10.0	10.0	9.4
Central....	9.6	10.1	10.2	10.4	8.9	7.6	6.8	6.4	7.3	8.2	9.4	9.6	8.7
Southern..	10.9	11.4	11.6	11.1	9.4	8.0	7.5	7.0	7.6	8.4	10.2	10.6	9.5
Average.	10.1	10.6	10.9	10.9	9.4	7.9	7.3	6.8	7.8	8.6	9.9	10.1	9.2

At the surface of the earth the air movement is much less than at a height of even a few feet, yet it is sufficient to play a very important part in increasing the amount of evaporation from the surface soil. Experiments have shown that when the air movement is 5 miles per hour, the amount of evaporation is increased 2.2 times over what it is during a calm; when 10 miles per hour, 3.8 times; when 15 miles, 4.9 times; when 20 miles, 5.7 times; when 25 miles, 6.1 times; and 30 miles per hour increases the evaporation 6.3 times. The effect of a windbreak on evaporation has been shown by an experiment in which it was determined that at 150 feet from a hedge the evaporation was 21.3 percent greater than at 20 feet, and at 300 feet, 30 percent greater.

The effect of a crop in preventing evaporation from the surface of the soil, thru the holding of a stratum of air possessing little movement and consequently becoming highly charged with moisture, is very striking. Hay and small grain crops are especially influential in this respect. In oat fields of heavy growth, the dew on the lower parts of the plants will not evaporate sometimes until nine or ten o'clock in the morning, and it begins to be deposited at four or five o'clock in the afternoon. On June 29, 1916, the relative humidity in a field of oats two inches above the soil and at the same height in the open, was determined during the day. The mean relative humidity in the oats was 80.4 percent, while in the open it was 53.4 percent, or a difference of 27 percent. This difference was due to shading and to lack of air movement in the oats. At six inches above the oats, the relative humidity was 58.6, and the average wind velocity was 3.2 miles per hour, while in the oats no movement occurred. It has been determined that for low wind velocity the increased evaporation rate due to wind is .5 percent per day for each mile of wind.

Air movement not only increases the evaporation from the soil, but also the amount of transpiration, or exhalation, of water from the leaves of the plant.

SUNSHINE AND CLOUDINESS

The amount of sunshine needed in the growth of crops varies somewhat with the crop, but all our principal cereals require sunshine during a large part of the time. Rather strong light is needed for the formation of starch.

December, January, February, March, and April are the cloudy months of the year, having sunshine for only 45.6 percent of the time possible, while the other months have sunshine for 56.4 percent of the time. August has the greatest amount of sunshine, 60.6 percent, while December has least, 42.3 percent. The extreme southern part of the state has the least amount of sunshine for the year, 47.7 percent. December and January in this district have only 39.3 percent.

TABLE 29.—AVERAGE AMOUNT OF SUNSHINE BASED ON AMOUNT OF POSSIBLE SUNSHINE
(Expressed in percentage)

District	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Aver.
Extreme northern	50.0	49.0	47.1	50.7	51.0	54.4	61.2	57.8	55.2	49.3	57.3	42.0	52.1
Central-northern	42.7	45.2	45.3	48.9	53.1	57.1	62.9	61.3	58.6	56.3	45.8	40.5	51.4
Central	47.3	47.0	45.2	48.6	52.1	54.6	59.7	62.7	60.4	61.1	54.8	45.7	53.3
Central-southern	46.8	47.5	48.8	52.8	56.7	58.5	62.3	63.4	62.0	63.4	55.0	44.1	55.1
Extreme southern	39.3	41.3	40.5	44.0	47.4	46.6	53.1	57.8	57.2	59.5	46.6	39.3	47.7
Average	45.2	46.0	45.4	49.0	52.1	54.2	59.8	60.6	58.7	57.9	51.9	42.3	51.9

Sunshine increases, not only the amount of evaporation from the soil, but also largely the loss of moisture from the leaves of plants by transpiration. When the soil is shaded, the loss of water by evaporation is checked. A soil shaded by dry rye plants evaporated 13.9 percent less than the same soil not so shaded.

RELATIVE HUMIDITY

The relative humidity is the percentage of moisture actually present in the air as compared with the amount which the air is capable of holding in vapor form. The relative humidity is lowered by a rise of temperature and increased by a lowering of temperature. A lowering of temperature causes deposition of dew. On the other hand, when clouds prevent the necessary lowering of temperature there is no dew.

At the Illinois Experiment Station the mean humidity for November, December, January, February, and March is 83.5 percent, while for the other months it is 74.2 percent, or 9.3 percent less.[1] The year 1911 had the lowest relative humidity of any year during which the humidity record has been kept at the University of Illinois. The mean humidity for May, June, July, and August of that year was 56 percent, and for the entire year 67.8 percent.

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[1] See Appendix, page 64.

APPENDIX

NOTE.—The detailed data with regard to precipitation and temperature appearing on pages 67 to 125 are taken from the published records of the United States Weather Bureau. Altho data for 1916 are included in the tables giving the precipitation for the various stations, the tables in the main part of the bulletin and the statements in the text take into account the records only so far as 1915.

METEOROLOGICAL SUMMARY FOR THE ILLINOIS AGRICULTURAL EXPERIMENT STATION AT URBANA: 1889 TO 1916

1889	TEMPERATURE			Rain-fall in inches	Mean relative humidity	Prevailing wind direction	No. of clear days	No. of partly cloudy days	No. of cloudy days
	Max.	Min.	Mean						
January...	57	-2	29.3	1.48	79.1	sw.	6	13	12
February..	53	-7.5	23.4	2.08	78.7	sw. & nw.	7	17	4
March.....	72	18	39.9	1.61	78.5	nw.	10	15	6
April......	75	25	51.9	.61	69.7	ne. & nw.	8	18	4
May......	91	28	59.2	5.52	74.9	sw.	1	24	6
June......	88	40	65.5	6.81	79.3	sw.	4	22	4
July......	90.5	50	72.7	5.81	80.0	s.	8	20	3
August....	89	29.5	69.2	.60	78.2	s.	..	..	..
September.	87.5	32	61.3	2.74	80.1	sw.	7	15	8
October....	82	25	47.3	1.42	75.2	nw.	15	12	4
November.	62	4	36.8	4.38	83.4	nw.	6	10	14
December..	66	15	42.7	1.82	82.6	sw.	8	15	8
Total......	......	......	......	34.88	......	....	80	177	73
Average...	76	21	49.9	2.91	78.3	sw.	7.3	16.1	6.6
1890									
January...	66	-5	33.5	5.26	88.0	nw.	6	15	10
February..	68	7	34.7	1.87	85.6	sw. & nw.	6	12	10
March.....	61	2	33.4	2.70	79.2	nw.	8	16	7
April......	81	29	52.3	4.11	73.1	ne.	10	15	5
May......	83	33	58.3	3.56	72.2	sw.	14	14	3
June......	96	47	74.6	3.80	77.4	sw.	13	16	1
July......	97.5	45	73.0	2.83	77.9	ne.	17	13	1
August....	96	44.5	68.7	1.93	71.9	nw.	15	15	1
September.	89	33	60.5	1.19	76.8	ne.	6	20	4
October....	76	27	52.1	2.35	79.2	nw.	3	21	7
November.	68	21	42.6	1.63	74.6	nw.	10	12	8
December..	58	8	30.9	.05	75.1	nw.	7	17	7
Total......	......	......	......	31.28	......	....	115	186	64
Average...	78.2	24.6	51.2	2.6	77.6	nw.	9.7	15.5	15.3
1891									
January...	57	6	30.3	.99	84.7	sw.	6	10	15
February..	61	-9	30.5	2.60	81.5	nw.	6	11	11
March.....	65	-1	32.6	3.55	84.9	ne. & nw.	4	16	11
April......	81	22	52.8	3.54	79.5	nw.	8	18	4
May......	91	30	58.4	.89	70.0	ne.	12	14	5
June......	93	49	71.9	2.08	78.5	sw.	9	15	6
July......	93	42	70.1	1.41	79.6	sw.	11	18	2
August....	99	40	70.2	2.86	74.0	nw.	2	27	2
September.	96	41	69.2	.41	66.0	s.	6	23	1
October...	88.5	27	51.3	1.29	72.9	s.	13	17	1
November.	67	2	35.7	5.58	83.1	s.	6	13	11
December..	60	11	37.0	1.53	79.2	s.	8	17	6
Total.....	......	....	......	26.73	......	....	92	199	75
Average...	79.3	21	50.8	2.22	77.8	s., sw.	7.6	16	6.1

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—*Continued*

1892	Temperature Max.	Temperature Min.	Temperature Mean	Rainfall in inches	Mean relative humidity	Prevailing wind direction	No. of clear days	No. of partly cloudy days	No. of cloudy days
January...	57	–15	19.2	.79	82.9	s.	6	20	5
February..	55	..	33.0	2.64	87.6	s.	2	14	13
March.....	69	..	36.1	2.59	82.1	sw.	3	22	6
April......	70.5	26	48.6	6.45	77.4	nw.	3	24	3
May......	82	36	57.9	7.86	81.1	sw.	1	23	7
June......	94	51	70.6	5.36	82.1	sw.	8	20	2
July......	96.5	46	73.3	2.50	80.4	s.	4	24	3
August....	94	47	71.5	2.45	81.1	w.	10	18	3
September.	87	42	63.9	.93	76.3	s.	14	15	1
October....	88.5	19	53.6	.93	70.5	s.	9	20	2
November.	64	7	34.8	4.95	83.7	s.	7	16	7
December..	60	–7	27.7	1.62	86.7	s.	4	16	11
Total.....	......	......	......	39.05	......	....	71	232	63
Average...	76.4	..	49.1	3.25	81.0	s.	5.9	19.3	5.3
1893									
January...	48	..	14.8	1.05	86.1	nw.	4	17	10
February..	51	..	25.8	4.48	87.5	nw.	5	14	9
March.....	76	..	37.8	3.20	79.6	s.	2	22	7
April.....	75	30	49.3	7.68	76.0	s.	1	19	10
May......	84	37	57.4	4.83	75.6	n. & sw.	4	24	3
June......	93	53	70.5	1.55	70.5	s.	6	18	6
July......	98	48	76.4	.59	71.9	s.	1	29	1
August....	96	37	71.1	.06	66.8	n.	11	19	1
September.	97	31	66.5	3.62	58.6	w.	4	19	7
October...	84	18	53.3	1.14	77.4	s.	9	18	4
November.	75	6	37.3	2.98	84.8	s.	6	16	8
December..	63	–6	30.0	1.09	84.4	s.	0	18	13
Total.....	......	......	......	32.37	....	....	53	223	79
Average...	78	..	49.1	2.69	76.6	s.	4.4	19	6.5
1894									
January...	64	–21	29.4	1.95	84.4	s.	3	18	10
February..	58	–5	24.7	1.32	81.2	w.	1	19	8
March.....	77	10	43.5	2.41	83.5	s.	4	21	6
April.....	85	25	51.4	1.86	78.6	s.	1	22	7
May......	89	32	59.6	3.32	80.7	s.	3	25	3
June......	97	34	73.4	1.78	75.4	s.	5	24	1
July......	98	47	73.8	1.08	68.9	s.	4	27	0
August....	99	41	72.3	2.06	72.2	w.	6	25	0
September.	94	38	65.0	4.21	84.6	s.	10	15	5
October...	84	28	51.9	.51	79.7	s.	5	21	5
November.	67	12	35.9	2.77	84.2	s.	3	18	9
December..	59	–4	32.9	1.44	86.2	s.	6	17	8
Total.....	......	......	......	24.72	....	....	51	252	62
Average...	81	19.7	51.1	2.06	79.9	s.	4.2	21	5.1

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—*Continued*

1895	Temperature			Rainfall in inches	Mean relative humidity	Prevailing wind direction	No. of clear days	No. of partly cloudy days	No. of cloudy days
	Max.	Min.	Mean						
January...	57	-2	29.2	1.36	93.3	nw.	9	14	8
February..	53	7.5	23.3	.52	91.7	nw.	8	17	3
March.....	84	7	35.9	.70	83.3	nw.	7	17	7
April......	88	27	52.3	2.42	78.0	ne.	7	17	6
May......	95	28	59.4	2.20	71.2	s.	14	16	1
June......	98.5	42	73.3	2.24	67.0	s.	10	18	2
July......	94	43	71.3	3.61	75.8	s.	5	22	4
August....	97	48	73.2	1.81	72.2	s.	6	21	4
September.	87.5	32	61.3	5.27	75.0	s.	12	15	3
October....	82	25	47.2	.21	65.2	nw.	14	15	2
November.	62	4	36.8	3.07	81.1	s.	3	14	13
December..	66	15	42.7	5.71	87.5	s.	2	13	16
Total.....	......	.....	......	29.12	....	....	97	199	69
Average...	80.3	18.7	55.1	2.42	78.4	s.	8	16	5.7
1896									
January...	52	-5	28.1	1.12	89.6	s.	2	13	16
February..	68	-4	29.6	1.95	81.8	sw. & nw.	3	14	12
March.....	67	6	34.4	1.22	83.0	nw.	5	19	7
April......	86	21	57.6	1.89	70.6	sw.	10	19	1
May......	91	45	68.2	5.62	76.2	s.	7	19	5
June......	92	49	70.2	2.98	78.4	s.	1	24	5
July......	95	49	73.8	7.87	76.3	s.	5	19	7
August....	97	44	72.0	3.74	80.0	s.	12	17	2
September.	91	30	61.9	5.84	81.4	s.	5	14	11
October....	79	24	48.8	.42	78.6	n.	18	9	4
November.	74	9	39.9	2.87	87.9	s.	6	13	11
December..	62	8	33.3	.39	87.0	sw.	3	20	8
Total.....	......	......	......	35.91	....	....	77	200	89
Average...	79	23	51.4	2.92	80.9	s.	6.4	16	7.4
1897									
January...	59	-15	22.0	4.53	95.0	nw.	10	10	11
February..	59	-2	30.0	1.17	90.0	nw. & n.	3	16	9
March.....	66	20	40.0	4.10	88.0	se.	3	17	11
April......	79	21	48.0	3.69	82.0	sw.	3	14	13
May......	83	31	58.0	1.81	77.0	nw.	6	21	4
June......	93	44	69.5	5.16	79.0	se.	1	7	22
July......	98	53	75.8	4.68	80.0	w. & nw.	10	12	9
August....	97	42	70.0	.63	79.2	nw.	13	16	2
September.	97.5	32	69.4	.31	68.5	sw.	24	5	1
October...	92	32	59.1	.42	71.0	s. & se.	20	8	3
November.	69	11	39.5	4.91	86.8	nw.	9	10	11
December..	59	1	26.3	2.67	93.7	nw.	2	16	13
Total.....	......	......	......	34.08	....	....	104	152	109
Average...	79.3	22.5	50.6	2.84	82.5	nw.	8.7	12.5	9.1

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—*Continued*

1898	Temperature			Rainfall in inches	Mean relative humidity	Prevailing wind direction	No. of clear days	No. of partly days	No. of cloudy days
	Max.	Min.	Mean						
January...	62	5	30.8	4.77	87.7	w.	6	11	14
February..	65	–6	30.3	1.43	94.2	nw.	3	7	18
March.....	69	15	39.4	7.76	90.2	nw.	6	17	8
April.....	79	22	48.5	2.71	77.3	nw.	3	20	7
May......	82	38	61.5	5.65	83.3	sw.	4	16	10
June......	90	49	73.6	6.08	80.5	sw.	8	17	5
July......	96	47	76.9	1.89	78.0	sw.	13	6	12
August....	94	53	74.0	3.61	84.0	sw.	9	18	4
September.	94	45	68.2	5.13	85.3	sw.	4	21	6
October...	86	40	51.4	4.53	86.9	s.	4	17	10
November.	68	..	36.1	3.01	88.8	sw.	11	11	8
December..	55	..	26.8	1.86	96.0	nw.	10	16	5
Total.....	......	......	......	48.43	....		81	177	107
Average...	78.3	..	51.5	4.03	86.0	sw.	6.7	14.7	8.9
1899									
January...	53	–12	25.5	1.97	96.4	sw.	5	19	7
February..	58	–25	18.4	2.33	96.4	sw.	6	16	6
March.....	65	–2	32.4	1.78	94.1	nw.	5	10	16
April......	90	15	53.1	.50	89.3	sw. & s.	5	20	5
May......	86	42	63.8	6.09	82.5	sw.	3	19	9
June......	93	50	71.4	2.29	78.3	s. & sw.	3	25	2
July......	94	51	74.4	2.65	79.3	sw.	7	19	5
August....	96	49	75.3	2.29	77.2	sw.	15	11	5
September.	99	24	63.1	1.07	74.6	sw.	11	14	5
October....	87	29	57.2	5.10	78.0	sw.	6	17	8
November.	69	17	43.8	1.39	88.5	ne. & sw.	0	19	11
December..	60	–6	27.8	2.14	87.6	nw.	0	17	14
Total.....	......	......	......	29.60	....		66	206	93
Average...	79.2	19.3	50.5	2.47	85.2	sw.	5.5	17.2	7.8
1900									
January...	61	–5	30.1	.17	92.9	w.	1	20	10
February..	63	–6	24.0	3.59	91.2	nw.	0	16	12
March.....	61	0	32.6	1.79	90.7	nw.	0	17	14
April......	83	24	51.2	.84	74.9	ne.	3	16	11
May......	89	33	63.3	4.60	74.6	sw.	1	24	6
June......	90	47	69.3	4.11	82.1	ne.	0	21	9
July......	93	51	74.2	3.81	79.4	sw.	2	5	24
August....	95	63	78.4	6.23	80.0	s.	4	26	1
September.	93	34	68.2	2.23	78.7	se. & sw.	1	24	5
October...	88	32	59.9	2.29	77.6	se.	1	25	5
November.	72	12	39.6	3.42	65.7	sw.	0	22	8
December..	58	1	29.9	1.00	73.9	sw.	2	21	8
Total.....	......	......	......	34.08	....		15	237	113
Average...	78.8	23.9	51.7	2.84	80.1	sw.	1.2	19.7	9.4

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—*Continued*

1901	Temperature			Rainfall in inches	Mean relative humidity	Prevailing wind direction	No. of clear days	No. of partly cloudy days	No. of cloudy days
	Max.	Min.	Mean						
January...	61	-7	27.8	1.55	92.6	nw.	0	16	15
February..	47	-2	21.0	1.41	92.1	nw.	1	21	6
March.....	70	5	37.6	3.14	85.2	sw.	0	12	19
April......	87	28	48.5	.80	72.7	se.	4	13	13
May......	89	38	59.2	1.93	82.1	ne.	2	21	8
June......	95	44	72.2	5.80	77.9	sw.	2	25	3
July......	104	48	79.5	2.48	77.4	sw.	2	29	0
August....	101	54	73.8	1.68	69.7	ne.	2	26	3
September.	94	33	64.6	1.38	75.6	sw.	4	22	4
October....	88	29	53.5	4.10	76.4	sw.	6	19	6
November.	69	16	35.8	1.31	80.5	nw.	0	25	5
December..	60	-15	24.2	3.06	88.8	nw.	0	16	15
Total......	......	......	......	28.64	....		23	245	97
Average...	80.4	22.7	49.8	2.39	80.9	sw.	1.9	20.4	8.1
1902									
January...	56	-7	25.7	.62	83.5	nw.	0	25	6
February..	48	-14	16.8	1.48	86.3	nw.	1	21	6
March.....	70	9	40.8	1.69	81.4	sw.	0	18	13
April.....	85	23	48.1	2.11	73.9	sw. & nw.	0	26	4
May......	90	40	65.8	2.60	75.0	se. & sw.	2	25	4
June......	92	45	68.4	[1]11.73	78.1	sw.	1	21	8
July......	91	50	74.6	4.02	77.1	sw.	13	14	4
August....	90	52	69.4	9.80	80.1	s.	6	19	6
September.	84	34	61.7	4.90	82.5	s.	3	15	12
October....	78	31	54.5	2.10	80.8	sw.	1	24	6
November.	75	14	46.6	2.42	83.0	sw.	0	18	12
December..	51	0	27.0	2.94	89.3	sw.	1	15	15
Total......	......	......	......	46.41	....		28	241	96
Average...	75.9	23.1	49.9	3.87	80.9	sw.	2.3	20.1	8
1903									
January...	53	-12	23.8	1.04	92.9	nw.	4	12	15
February..	55	-17	25.6	2.40	96.0	sw.	0	13	15
March.....	76	15	44.2	1.43	85.0	sw.	2	22	7
April.....	80	19	50.8	5.71	75.5	sw.	2	20	8
May......	86	26	64.0	3.95	71.4	sw.	3	20	8
June......	90	40	65.5	2.56	75.3	sw.	2	24	4
July......	96	54	74.8	5.13	72.2	sw.	3	23	5
August....	94	52	71.6	2.33	80.2	sw.	1	24	6
September.	90	35	65.6	.99	74.9	s. & sw.	10	19	1
October....	88	21	54.2	2.70	72.3	sw.	15	14	2
November.	68	8	36.1	2.06	87.4	s. & nw.	8	17	5
December..	45	-7	22.2	2.18	84.0	nw. & sw.	5	22	4
Total......	......	......	......	32.48	....		55	231	80
Average...	77	20	49.8	2.70	80.6	sw.	4.5	19.2	6.6

[1] The storm during the night of June 10 blew the rain gage over, but 0.75 inch is included, which was about the rainfall during the storm.

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—*Continued*

1904	TEMPERATURE			Rainfall in inches	Mean relative humidity	Wind		No. of clear days	No. of partly cloudy days	No. of cloudy days
	Max.	Min.	Mean			Average velocity[1]	Direction			
January...	50	–15	17.9	3.09	88.1	...	nw.	4	18	9
February..	60	–11	21.7	1.86	81.7	12.6	nw.	3	20	6
March....	72	11	38.4	7.66	84.3	12.3	se.	5	18	8
April.....	80	22	45.2	3.97	72.9	12.4	ne.	8	18	4
May......	87	38	61.2	1.60	68.4	9.4	se.	10	19	2
June......	88	40	68.8	1.17	71.4	9.3	sw.	9	21	0
July......	92	41	72.5	2.61	70.0	7.2	sw.	11	18	2
August....	91	46	70.3	3.55	69.3	6.7	sw.	13	16	2
September.	89	41	66.1	2.53	78.0	7.9	sw.	12	16	2
October...	81	28	53.0	.81	75.0	8.9	sw.	16	14	1
November.	69	14	42.2	T	79.4	8.4	sw.	13	15	2
December..	55	2	27.7	.83	74.0	11.8	sw.	7	17	7
Total.....	......	......	......	29.68	....	...	...	111	210	45
Average...	76	21	48.7	2.47	76.0	...	sw.	9.2	17.5	3.7
1905										
January...	58	–11	19.2	1.80	88.6	10.1	n.	6	19	6
February..	49	–25	16.8	2.27	88.4	10.4	nw.	10	12	6
March....	77	20	44.0	.75	...	10.2	s.	..	..	..
April.....	83	26	50.6	2.95	...	10.1	w.	..	..	..
May......	85	40	62.6	4.24	...	10.1	s.	6	25	0
June......	97	46	71.1	1.30	...	7.6	s.	4	25	1
July......	92	52	72.9	5.40	...	7.2	sw.	5	20	6
August....	94	54	74.7	2.14	...	6.6	s.	8	20	3
September.	93	46	67.4	2.88	...	7.4	s.	10	12	8
October...	86	27	52.3	3.11	...	8.2	sw.	15	9	7
November.	74	13	39.5	1.45	...	12.5	w.	9	16	5
December.	52	3	29.8	1.31	...	10.5	w.	11	14	6
Total.....	......	......	......	29.60	....	...	...	..	..	..
Average...	78	24	50.0	2.46	...	8.4	s.	..	..	..
1906										
January...	67	2	32.3	1.65	...	12.4	..	6	14	11
February..	62	–7	27.4	1.11	...	10.0	..	11	11	6
March....	53	–5	29.0	4.61	...	12.8	..	6	6	19
April.....	84	26	54.1	2.23	...	10.1	..	18	8	4
May......	88	30	62.2	3.31	...	9.5	..	14	16	1
June......	93	46	68.9	3.08	...	9.5	..	11	15	4
July......	92	52	73.2	2.16	...	...	..	12	19	0
August...	94	47	75.3	4.57	...	...	..	13	15	3
September.	91	48	69.1	2.45	...	...	..	13	13	4
October...	78	20	53.1	1.36	...	10.2	..	11	13	7
November.	70	20	40.2	4.59	...	...	..	7	13	10
December.	61	7	32.6	3.13	...	...	..	2	11	18
Total.....	......	......	......	34.25	....	...	..	124	154	87
Average...	78	24	51.4	2.85	...	...	..	10.3	12.8	7.2

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[1] Miles per hour.

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—*Continued*

1907	TEMPERATURE			Rainfall in inches	Mean relative humidity	Wind		No. of clear days	No. of partly cloudy days	No. of cloudy days
	Max.	Min.	Mean			Average velocity	Direction			
January..	64	0	31.0	6.09	...	...	n.	4	6	21
February..	58	–3	28.9	.24	...	...	..	9	15	4
March....	85	21	46.6	3.34	...	...	s.	5	17	9
April.....	77	22	42.6	2.34	...	...	..	..	..	..
May......	84	30	54.4	5.04	76.6	...	e.	10	11	10
June.....	90	42	66.7	5.56	75.7	...	n.	8	14	8
July......	93	48	74.2	5.41	83.0	...	w.	5	19	7
August...	92	50	71.2	4.42	84.0	...	w.	5	20	6
September	90	36	65.0	.94	80.1	...	nw.	14	10	6
October...	89	28	51.4	1.51	75.8	...	sw.	20	1	10
November.	60	16	37.8	1.99	78.8	...	w.	5	20	3
December.	62	13	32.1	3.32	88.7	...	w.	6	9	16
Total.....	......	......	......	40.20	...	...	..	..	..	..
Average...	79	25	50.2	3.35	...	...	..	..	..	..
1908										
January..	52	2	28.8	1.21	82.4	11.0	sw.	13	7	11
February..	53	–2	27.2	4.09	87.1	12.4	e.	8	6	15
March....	76	24	43.0	3.20	81.9	10.8	sw.	10	19	2
April.....	78	20	50.3	5.00	79.8	11.4	sw.	8	10	12
May......	85	34	61.8	7.83	81.2	10.7	sw.	2	23	6
June.....	92	41	69.2	1.99	72.2	9.2	sw.	3	26	1
July......	94	50	73.9	2.31	74.2	6.4	sw.	5	24	2
August...	93	51	72.8	2.05	68.9	6.8	sw.	6	25	0
September	93	33	69.1	1.95	68.4	7.3	se.	7	23	0
October...	86	27	54.0	.21	84.3	8.0	se.	9	19	3
November.	70	14	42.4	1.99	77.9	10.0	sw.	9	17	4
December.	62	4	32.0	1.44	76.3	9.9	sw.	3	24	4
Total.....	......	......	......	33.27	....	...	..	83	223	60
Average...	78	25	52.0	2.77	77.9	9.5	sw.	6.9	18.5	5
1909										
January..	70	–2	28.4	2.17	90.1	10.5	nw.	0	20	11
February..	60	1	32.9	5.80	87.9	12.4	sw.	0	21	7
March....	63	14	38.1	1.76	80.0	11.1	nw.	0	28	3
April.....	80	22	49.2	7.44	80.0	12.1	w.	1	25	4
May......	85	32	58.8	5.58	74.2	11.4	ne.	4	24	3
June.....	91	42	70.2	3.75	78.1	6.4	sw.	4	25	1
July......	93	49	71.0	7.57	74.2	7.2	ne.	7	20	4
August...	94	50	75.4	2.37	68.9	5.7	ne.	10	21	0
September	90	36	63.4	2.36	72.8	7.2	se.	9	20	1
October...	80	21	49.0	2.25	72.4	8.5	w.	10	18	3
November.	74	19	49.8	3.45	79.5	11.2	sw.	4	21	5
December.	60	–13	20.2	2.55	92.2	9.5	w.	3	19	9
Total.....	......	......	......	47.05	....	...	...	52	262	51
Average...	78	22	50.5	3.92	79.2	9.4	w.	4.3	21.8	4.2

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—*Continued*

1910	Temperature			Rainfall in inches	Mean relative humidity	Wind		No. of clear days	No. of partly cloudy days	No. of cloudy days
	Max.	Min.	Mean			Average velocity	Direction			
January...	47	−1	27.0	2.23	88.2	9.3	w.	2	21	8
February..	59	−12	25.2	1.79	79.8	10.3	s.	4	19	5
March.....	85	17	50.3	.38	66.9	9.8	sw.	11	18	2
April.....	84	23	52.0	1.57	70.9	10.3	sw.	6	18	6
May......	79	34	57.0	5.35	71.2	9.3	ne.	1	28	2
June......	95	38	69.6	2.99	64.9	6.8	ne.	4	25	1
July......	93	34	74.8	2.76	74.3	6.9	sw.	9	19	3
August....	90	46	71.0	2.62	74.9	6.4	sw.	9	17	5
September.	87	41	65.9	4.14	78.3	6.9	s.	8	16	6
October...	83	21	57.0	1,34	70.3	7.1	sw.	14	14	3
November.	70	17	36.6	1.20	71.6	8.8	nw.	7	18	5
December..	46	4	25.6	1.59	76.7	9.9	nw.	8	15	8
Total.....	......	......	......	27.96	....	...	...	83	228	54
Average...	76	22	51.0	2.33	74.0	8.5	sw.	6.9	19.0	4.5
1911										
January...	58	0	29.4	2.27	78.0	10.7	sw.	8	16	12
February..	69	11	33.7	1.19	78.6	10.3	w.	4	17	7
March.....	73	10	39.6	1.85	67.4	10.8	w.	8	20	3
April.....	72	26	48.5	3.50	70.3	10.7	se.	4	14	12
May......	95	34	67.4	2.44	58.1	8.5	s.	11	19	1
June......	98	50	74.4	.82	57.8	7.4	sw.	9	21	0
July......	102	47	75.3	.62	51.8	6.9	sw.	12	19	0
August....	97	49	73.0	3.35	57.2	6.7	ne.	8	20	3
September.	90	43	67.8	8.90	70.1	7.0	sw.	4	16	10
October...	84	29	53.6	3.10	60.2	6.4	ne.	4	21	6
November.	75	9	35.0	2.83	77.0	11.0	...	1	21	8
December..	61	8	33.4	1.35	86.7	9.6	sw.	4	16	11
Total.....	......	......	......	32.22	....	...	...	72	220	73
Average...	81	26	52.5	2.69	67.8	8.8	sw.	6.0	18.3	6.0
1912										
January...	42	−22	13.8	1.36	90.7	10.1	sw.	0	22	9
February..	49	−10	21.5	2.28	83.6	7.6	sw.	2	20	7
March....	70	10	30.4	3.42	85.0	8.8	ne.	4	19	8
April.....	75	29	52.3	5.60	80.1	11.0	sw.	7	17	6
May......	87	37	63.8	4.16	78.1	9.2	se.	5	21	5
June......	88	41	67.4	1.89	70.8	6.5	sw.	6	19	5
July......	94	55	74.2	3.68	82.5	7.2	s.	3	21	7
August....	92	47	71.4	2.06	80.2	7.0	sw.	5	23	3
September.	95	35	67.6	1.76	77.0	5.8	...	10	17	3
October...	85	28	56.1	2.95	73.9	7.7	s.	13	12	6
November.	72	16	41.8	1.77	76.5	10.0	sw.	9	15	6
December.	58	4	33.2	.57	75.9	10.8	sw.	9	16	6
Total.....	......	......	......	31.50	....	...	...	73	222	71
Average...	75	22	49.4	2.62	79.5	8.5	sw.	6.0	18.5	5.9

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—*Continued*

1913	TEMPERATURE			Rainfall in inches	Mean relative humidity	Wind		No. of clear days	No. of partly cloudy days	No. of cloudy days
	Max.	Min.	Mean			Average velocity	Direction			
January...	58	3	30.8	5.38	80.5	10.0	s.	1	16	14
February..	64	–9	24.3	1.10	83.1	9.4	sw.	7	14	7
March.....	66	–1	37.0	5.99	81.6	13.0	s.	4	19	8
April.....	80	31	51.4	2.19	70.1	10.7	s.	6	17	7
May......	89	33	63.0	.56	63.4	9.7	sw.	5	17	9
June......	98	40	72.5	1.67	63.8	7.1	sw.	11	16	3
July......	103	51	78.2	1.52	60.7	6.7	sw.	9	22	0
August....	100	55	77.5	1.44	59.7	6.7	s.	9	18	4
September.	98	37	69.6	2.50	66.0	7.4	e.	6	15	9
October...	82	26	52.8	4.03	73.8	7.2	sw.	8	16	7
November.	72	16	47.5	4.49	75.9	9.0	s.	5	10	15
December..	58	16	36.3	.77	83.5	7.0	sw.	7	5	19
Total.....	......	......	......	31.64	....	...	...	78	185	102
Average...	80	25	53.4	2.64	71.8	8.7	sw.	6.5	15.4	8.5
1914										
January...	64	8	33.6	1.97	82.6	10.4	sw.	2	12	17
February..	44	–1	20.4	2.50	85.1	7.6	ne.	3	18	7
March.....	68	8	37.1	.89	82.7	9.7	sw.	1	17	13
April.....	83	22	51.7	2.87	71.7	10.9	nw.	1	16	13
May......	92	41	67.5	1.94	58.7	8.3	sw.	6	21	4
June......	97	52	77.6	2.40	59.0	6.4	sw.	0	26	4
July......	99	62	80.5	1.44	54.8	5.9	ne.	12	16	3
August....	95	60	76.4	2.65	63.1	6.7	sw.	4	23	4
September.	88	41	65.5	2.11	69.4	6.9	s.	10	16	4
October...	82	24	57.3	2.85	72.2	6.2	s.	10	11	10
November.	70	5	44.1	.80	63.4	8.9	sw.	8	19	3
December..	58	–13	22.1	2.25	85.9	8.8	ne.	1	12	18
Average...	......	......	......	24.67	....	...	...	58	207	100
Total.....	78	25	52.8	2.05	70.7	8.1	sw.	4.8	17.2	8.3
1915										
January...	49	–15	23.7	1.81	86.7	8.6	s.	6	9	16
February..	60	14	35.9	2.33	82.8	10.6	sw.	6	6	16
March....	55	20	35.4	1.12	77.6	7.6	nw.	3	15	13
April.....	84	26	59.3	1.59	65.0	8.9	s.	12	11	7
May......	86	39	60.5	5.11	72.3	8.9	sw.	6	6	19
June......	86	43	70.6	2.98	70.2	7.0	ne.	4	18	8
July......	90	50	74.1	7.30	73.1	5.9	sw.	1	24	6
August....	85	39	67.4	4.90	75.2	6.6	ne.	3	9	19
September.	88	42	67.9	2.58	76.5	6.3	s.	11	10	9
October...	80	31	56.3	.64	64.1	6.9	sw.	17	9	5
November.	79	12	44.2	1.02	71.1	10.5	w.	7	7	16
December..	46	6	29.0	2.85	83.7	8.2	nw.	3	6	22
Total.....	..	..	...	34.23	...	..	...	79	130	156
Average...	74	25	52.0	2.85	74.9	8.0	sw.	6.4	10.8	13.0

METEOROLOGICAL SUMMARY FOR THE EXPERIMENT STATION—*Concluded*

1916	Temperature			Rainfall in inches	Mean relative humidity	Wind		No. of clear days	No. of partly cloudy days	No. of cloudy days
	Max.	Min.	Mean			Average velocity	Direction			
January...	61	–9	29.7	6.02	84.3	11.3	s.	9	3	19
February..	61	–7	26.6	.63	79.8	9.0	nw.	8	7	14
March....	77	1	37.4	1.14	79.0	10.7	n.	7	9	15
April.....	80	26	50.6	1.28	68.9	10.2	nw.	6	3	21
May......	88	36	64.0	5.70	71.1	9.1	sw.	7	10	14
June......	92	52	67.9	3.88	74.0	8.0	sw.	9	11	10
July......	101	61	82.3	.47	61.9	5.2	ne.	24	4	3
August...	97	50	78.2	1.72	64.7	5.6	sw.	15	7	9
September.	92	32	65.2	2.69	64.7	6.6	sw.	13	9	8
October...	86	30	54.4	2.26	66.0	6.8	s.	16	4	11
November.	75	12	43.4	1.93	69.5	10.4	sw.	15	7	8
December.	66	–6	27.6	1.99	77.6	9.6	w.	11	13	7
Total.....	..	..	...	29.71	...	..	...	140	87	139
Average..	81	23	52.3	2.48	71.8	8.5	sw.	11.7	7.2	11.6

CONDENSED METEOROLOGICAL SUMMARY FOR THE ILLINOIS AGRICULTURAL EXPERIMENT STATION AT URBANA: 1889 TO 1916

Month	Temperature			Rainfall in inches	Mean relative humidity	Wind		No. of clear days	No. of partly cloudy days	No. of cloudy days
	Max.	Min.	Mean			Average velocity	Direction			
January..	57.2	–5.8	26.5	2.35	87.5[2]	10.4[5]	nw.[1]	4.3	15.3	11.4
February.	57.5	–5.5	26.2	2.08	86.2[2]	10.3[4]	nw.[2]	4.4	15.0	8.7
March....	70.2	9.8	38.0	2.70	82.2[3]	10.7[4]	nw.[1]	4.5[1]	17.7[1]	9.0[1]
April.....	80.5	24.3	50.8	3.12	75.2[3]	10.8[4]	sw.[2]	5.6[2]	17.4[2]	7.0[2]
May......	87.1	34.8	61.3	4.04	73.8[2]	9.6[4]	sw.[1]	5.8	19.8	5.3
June.....	92.9	44.9	70.5	3.50	73.7[2]	7.6[4]	sw.[1]	5.4	20.3	4.3
July......	95.4	49.1	74.6	3.33	73.5[2]	6.7[5]	sw.[1]	7.3	19.3	4.4
August...	94.1	47.9	72.7	3.17	73.6[2]	6.6[5]	sw.[1]	7.9[1]	19.6[1]	3.5[1]
September	91.6	36.7	65.9	2.79	74.6[2]	7.0[5]	s.[2]	8.7	16.3	5.0
October...	83.1	26.1	53.4	2.00	74.8[2]	7.8[4]	sw.[1]	10.6	15.3	5.0
November.	70.0	12.0[1]	40.0	2.75	79.4[2]	10.0[5]	sw.[2]	11.0	15.8	8.3
December.	58.1	1.8[1]	30.4	2.33	82.4[2]	9.6[5]	sw.[1]	4.8	15.6	10.9
Total.....	...	...	...	34.16	...	...	...	80.3	207.4	82.8
Average..	78.1	23.1	50.8	2.84	78.1	8.9	sw.	6.7	17.3	6.9

[1] Average of 27 years.
[2] Average of 26 years.
[3] Average of 25 years.
[4] Average of 12 years.
[5] Average of 11 years.

AGRICULTURAL EXPERIMENT STATION, URBANA: ANNUAL PRECIPITATION FOR GROWING SEASON, BY TEN-DAY PERIODS

	1889	1890	1891	1892	1893	1894	1895	1896	1897
April 1 – 10	0.05	1.10	1.68	3.32	1.39	0.67	1.81	0.71	1.70
April 11 – 20	0.54	1.40	1.35	1.17	3.76	1.03	0.13	0.60	0.54
April 21 – 30	0.02	1.61	0.51	1.96	2.53	0.19	0.47	0.58	1.98
May 1 – 10	0.00	0.68	0.00	1.90	0.36	2.17	0.19	1.39	0.83
May 11 – 20	0.38	1.61	0.46	2.75	0.68	0.02	1.98	2.22	0.61
May 21 – 31	5.14	1.27	0.43	3.21	3.79	1.15	0.03	1.76	0.36
June 1 – 10	3.47	0.40	0.55	0.30	1.26	0.02	0.01	1.85	...
June 11 – 20	3.22	3.40	1.20	3.05	0.25	0.53	0.72	0.88	...
June 21 – 30	1.31	0.00	0.33	2.01	0.04	1.23	1.51	0.25	...
July 1 – 10	0.39	0.81	0.07	1.37	0.05	0.05	0.45	1.20	2.97
July 11 – 20	2.76	1.23	0.51	0.86	0.35	0.30	2.37	2.64	1.30
July 21 – 31	2.66	0.79	0.83	0.27	0.19	0.73	0.79	4.03	0.41
Aug. 1 – 10	0.03	1.07	0.03	2.35	0.00	1.19	0.00	1.28	0.21
Aug. 11 – 20	0.57	0.14	2.61	0.00	0.06	0.53	0.00	2.25	0.28
Aug. 21 – 31	0.00	0.72	0.22	0.08	0.00	0.34	1.81	0.21	0.14
Sept. 1 – 10	1.30	0.64	0.35	0.55	0.00	3.54	3.20	2.48	0.31
Sept. 11 – 20	0.00	0.18	0.00	0.38	1.22	0.50	1.55	0.89	0.00
Sept. 21 – 30	1.44	0.37	0.06	0.00	2.40	0.17	0.52	2.10	0.00
Total.......	23.28	17.42	11.19	25.53	18.33	14.36	17.54	27.32	...

ANNUAL PRECIPITATION FOR GROWING SEASON—*Continued*

	1898	1899	1900	1901	1902	1903	1904	1905	1906	1907
April 1 – 10	0.33	0.00	0.00	0.32	0.00	3.35	1.42	0.22	1.75	0.54
April 11 – 20	0.73	0.25	0.74	0.45	0.31	1.90	0.00	0.00	0.42	0.10
April 21 – 30	1.63	0.25	0.10	0.03	1.80	0.46	2.55	2.73	0.06	1.70
May 1 – 10	0.14	0.38	1.70	1.10	2.03	0.00	0.62	1.23	1.01	0.85
May 11 – 20	3.70	2.07	1.90	0.05	0.41	0.03	0.32	1.33	1.04	1.15
May 21 – 31	1.81	3.64	1.00	0.78	0.16	3.92	0.66	1.68	1.26	2.96
June 1 – 10	2.79	0.93	0.69	1.23	1.81	1.88	0.30	1.18	1.95	3.66
June 11 – 20	0.75	0.60	0.30	1.79	3.23	0.30	0.62	0.06	1.13	0.00
June 21 – 30	2.54	0.76	3.12	2.78	5.94	0.38	0.25	0.06	0.00	1.90
July 1 – 10	0.00	0.57	0.18	2.40	0.47	1.28	2.12	3.31	0.11	2.05
July 11 – 20	0.85	1.67	2.53	0.08	1.67	2.79	0.32	1.97	1.50	1.49
July 21 – 31	1.04	0.41	1.10	0.00	1.88	1.06	0.28	0.12	0.55	1.47
Aug. 1 – 10	1.84	1.59	0.23	0.00	3.15	0.48	0.50	0.00	0.93	2.01
Aug. 11 – 20	0.70	0.06	5.08	1.04	6.65	0.60	1.46	2.14	2.83	2.34
Aug. 21 – 31	1.07	0.64	0.92	0.64	0.00	1.25	1.59	0.00	0.81	0.07
Sept. 1 – 10	2.44	0.88	0.12	0.10	0.83	0.09	0.00	2.56	0.05	0.41
Sept. 11 – 20	0.70	0.17	1.05	1.28	0.76	0.41	2.02	0.26	0.12	0.04
Sept. 21 – 30	2.05	0.02	1.06	0.00	3.31	0.49	0.51	0.06	2.28	0.49
Total..	25.11	14.89	21.82	14.07	34.41	20.67	15.54	18.91	17.80	23.23

ANNUAL PRECIPITATION FOR GROWING SEASON—*Concluded*

	1908	1909	1910	1911	1912	1913	1914	1915	1916	Average
April 1-10	1.72	2.40	0.10	1.45	1.28	1.52	2.18	0.82	0.19	1.14
April 11-20	0.47	2.81	0.72	1.68	2.12	0.06	0.08	0.02	0.76	0.86
April 21-30	2.81	2.23	0.75	0.46	2.20	0.61	0.61	0.75	0.33	1.14
May 1-10	4.22	1.88	1.82	0.61	0.59	0.06	1.07	1.93	0.80	1.06
May 11-20	2.87	0.22	1.14	1.21	2.52	0.00	0.82	0.17	2.37	1.22
May 21-31	0.74	3.46	2.39	0.62	1.05	0.50	0.05	3.01	2.53	1.76
June 1-10	0.09	1.01	0.24	0.08	0.38	0.00	0.95	0.13	1.39	1.06
June 11-20	0.76	1.09	0.00	0.06	1.51	0.00	0.88	2.21	1.38	1.11
June 21-30	1.14	1.65	2.75	0.68	0.00	1.67	0.57	0.64	1.11	1.28
July 1-10	0.68	3.61	0.05	0.00	1.22	0.77	0.24	3.16	0.07	1.06
July 11-20	1.33	3.79	1.82	0.36	0.00	0.12	0.86	0.44	0.40	1.30
July 21-31	0.30	0.17	0.89	0.26	2.46	0.63	0.34	3.70	0.26	0.99
Aug. 1-10	0.00	0.03	0.22	0.54	0.66	0.06	0.50	1.06	0.17	0.72
Aug. 11-20	1.95	0.01	1.45	0.00	1.18	1.16	0.96	2.97	1.27	1.40
Aug. 21-31	0.10	2.33	0.95	2.81	0.22	0.22	1.19	0.87	0.02	0.69
Sept. 1-10	0.48	0.36	2.45	3.45	0.30	0.01	2.01	0.16	1.67	1.10
Sept. 11-20	0.00	0.16	0.52	1.65	1.07	2.07	0.06	1.96	0.00	0.68
Sept. 21-30	1.47	1.84	1.17	3.80	0.39	0.42	0.04	0.46	1.02	1.00
Total..	21.13	29.05	19.43	19.72	19.15	9.88	13.41	24.46	15.74	...

PRECIPITATION FOR EXTREME NORTHERN DISTRICT BY STATIONS

ANTIOCH, LAKE COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1901	...	...	...	...	...	...	2.85	1.31	1.97	0.61	0.66	0.90	....
1902	0.45	1.40	1.95	1.30	7.45	5.90	6.25	0.55	7.35	3.67	1.80	0.70	38.77
1903	0.35	0.60	2.60	2.55	3.65	2.90	6.60	7.95	6.35	0.80	0.70	1.10	36.15
1904	0.55	1.10	5.20	2.20	1.90	1.39	4.41	2.20	4.55	1.20	0.75	1.30	26.75
1905	1.00	2.05	2.65	...	4.45	2.95	5.80	5.20	2.80	...	1.70	1.55	....
1906	3.20	2.40	0.60	1.95	2.10	2.95	1.65	5.33	5.87	2.25	3.30	1.15	32.75
1907	3.80	0.30	1.65	0.95	5.29	4.80	2.02	3.96	5.43	1.05	1.87	2.10	33.22
1908	2.55	2.20	3.35	4.85	5.26	3.60	4.29	1.57	1.00	1.15	2.70	1.00	33.52
1909	2.20	1.60	0.00	8.68	1.05	2.00	1.15	6.55	3.62	0.61	3.23	3.50	34.19
1910	2.20	0.65	0.05	2.94	4.94	1.30	0.83	3.61	2.80	2.37	2.00	*1.11	24.80
1911	0.80	2.88	0.23	5.57	3.10	4.00	1.28	5.73	6.16	4.16	5.29	2.50	41.70
1912	0.50	*0.30	1.69	2.69	3.66	2.02	8.70	2.34	2.25	5.62	1.75	1.31	32.83
1913	1.81	1.28	2.53	2.35	5.47	2.07	3.45	1.81	3.10	5.51	1.62	T	31.00
1914	2.63	1.27	2.71	1.86	6.76	4.80	3.33	1.87	3.98	3.47	0.59	2.68	35.95
1915	1.71	2.40	1.75	0.63	7.92	3.37	4.20	2.48	7.93	2.01	2.85	0.40	37.65
1916	4.11	1.41	...	...	...	7.64	2.03	1.97	3.77	4.27	2.07	...	....

*Estimated from surrounding stations.

DUBUQUE, DUBUQUE COUNTY, IOWA

1873	...	...	...	...	...	...	1.27	5.88	1.53	2.07	0.77	2.07	....
1874	2.45	0.49	1.28	1.54	1.08	3.29	3.24	2.13	7.68	2.18	4.79	0.65	30.80
1875	1.00	2.12	1.45	2.71	3.62	4.75	5.74	1.07	7.10	2.71	0.48	2.71	35.46
1876	3.20	1.53	4.00	3.63	5.96	7.88	8.15	5.92	5.90	1.10	2.49	0.52	50.28
1877	0.96	0.26	4.53	3.74	3.84	6.75	2.90	3.96	0.67	5.35	3.31	2.70	38.97
1878	0.49	1.93	2.44	4.34	4.61	4.35	6.71	1.72	6.94	2.85	0.80	1.12	38.30
1879	0.44	1.00	1.20	2.02	2.94	4.99	6.78	2.43	2.98	0.93	5.41	1.28	32.40
1880	1.95	1.01	2.55	3.51	3.72	6.02	3.55	7.15	6.84	0.66	2.11	1.25	40.32
1881	1.87	3.75	3.78	1.30	2.20	7.56	10.53	2.46	10.26	6.70	3.19	1.55	55.15
1882	0.84	0.59	1.49	4.47	4.16	6.29	1.48	2.29	2.60	5.29	1.55	1.79	32.84
1883	1.59	2.60	0.32	1.93	7.13	5.34	7.90	2.70	2.09	4.44	1.65	1.88	39.57
1884	0.99	2.19	3.85	2.77	4.88	4.89	5.30	4.25	4.07	4.16	1.43	4.08	42.86
1885	1.80	0.72	0.41	3.69	2.62	6.16	6.35	8.02	4.58	2.32	0.64	3.14	40.45
1886	3.17	1.36	4.32	2.12	4.17	0.71	0.89	0.67	3.10	4.08	1.89	1.03	27.51
1887	3.33	3.56	1.80	1.37	2.53	1.32	2.44	4.40	7.62	2.22	0.74	3.07	34.40
1888	1.20	1.31	3.44	2.58	5.84	5.28	3.59	1.73	2.01	1.62	2.75	1.96	33.31
1889	1.55	1.34	0.30	3.56	4.00	3.87	4.22	0.26	1.54	0.66	1.57	1.38	24.25
1890	2.31	1.25	1.68	2.94	5.36	9.59	1.21	6.00	3.72	6.43	1.85	0.82	43.16
1891	1.27	0.98	2.69	1.63	2.54	2.34	4.59	3.31	0.68	2.20	3.24	2.08	27.55
1892	2.34	1.02	1.91	4.37	9.18	14.16	5.08	2.51	3.79	0.44	1.89	2.08	48.77
1893	1.60	1.30	2.52	4.32	3.06	5.49	3.57	0.58	3.31	1.66	2.03	1.33	30.77
1894	1.11	1.22	3.06	2.27	1.75	2.25	0.02	1.32	2.96	1.51	1.53	0.35	19.35
1895	1.44	0.66	0.99	0.49	2.63	1.05	3.00	1.75	2.06	0.80	2.12	2.75	19.74
1896	0.75	1.93	0.76	7.80	7.63	3.11	7.72	2.05	5.67	2.56	1.60	0.71	42.29
1897	2.55	1.43	2.97	3.39	2.09	2.36	4.34	1.51	3.19	1.02	1.23	2.08	28.16
1898	2.19	2.01	2.78	4.06	4.47	4.36	2.83	4.37	3.07	3.86	1.15	0.33	35.48
1899	0.51	0.67	1.52	4.24	5.75	4.08	4.12	1.95	0.99	1.63	0.97	1.85	28.28
1900	1.15	2.18	1.84	2.39	4.75	2.04	8.00	3.35	3.34	2.38	1.64	0.42	33.48
1901	1.07	1.07	2.88	1.01	3.10	1.23	2.31	0.25	3.72	1.64	0.67	1.44	20.39
1902	0.74	1.43	1.76	1.11	8.67	6.97	6.80	1.57	3.93	2.26	0.86	2.24	38.34
1903	0.17	1.19	1.84	3.29	4.25	2.16	7.10	5.27	3.20	1.72	0.75	0.85	31.79
1904	0.51	0.78	2.86	2.05	3.86	0.74	1.86	2.58	2.21	3.18	0.08	2.37	23.08
1905	0.95	1.58	2.27	3.07	4.06	4.83	1.51	3.07	1.25	3.38	2.64	1.17	29.78
1906	2.72	0.93	2.36	1.16	3.59	3.36	1.57	4.44	1.78	1.70	2.95	2.04	28.60
1907	1.72	0.52	0.99	2.48	2.66	4.08	5.15	5.85	6.01	0.77	1.29	0.67	32.19
1908	0.70	1.87	1.72	2.50	5.82	2.21	2.06	2.92	1.14	1.20	1.34	0.63	24.11
1909	1.98	1.32	1.25	7.40	2.32	6.61	1.30	1.50	4.28	2.03	2.94	2.08	35.01
1910	2.45	0.50	0.14	3.40	3.42	2.43	0.47	3.96	3.10	0.89	0.53	0.57	21.86
1911	0.72	4.09	0.52	3.17	2.84	2.83	4.41	8.74	3.56	2.34	3.04	1.95	38.21
1912	0.55	1.77	2.07	2.49	5.98	1.93	4.81	6.79	4.42	3.50	1.51	1.00	36.82
1913	1.11	0.82	2.81	1.70	8.20	1.92	2.31	3.60	3.59	2.92	1.23	0.34	30.55
1914	0.78	1.16	1.74	1.53	4.64	5.81	1.57	4.01	4.75	2.88	0.21	1.83	30.91
1915	2.01	2.48	1.14	0.38	7.61	3.06	5.08	2.84	9.62	2.03	1.65	0.36	38.26
1916	2.46	0.76	3.91	2.69	2.49	4.61	0.85	1.49	6.19	3.32	1.17	0.95	30.89

KISHWAUKEE, WINNEBAGO COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	•July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1872	....	....	....	....	....	....	....	....	....	....	....	0.76	.....
1873	1.80	....	1.56	1.50	4.75	3.00	1.60	1.65	1.55	2.70	1.60	2.25	.....
1874	4.87	0.83	1.01	1.28	1.09	3.39	0.90	1.19	5.97	1.10	1.73	0.57	23.88
1875	0.75	1.56	0.59	3.06	2.25	6.21	5.96	2.15	3.56	2.34	0.51	2.57	31.51
1876	3.46	2.91	2.84	3.83	6.06	4.25	5.80	2.42	4.71	1.50	4.37	0.41	42.56
1877	3.06	0.30	5.53	3.99	2.20	4.32	1.96	4.04	0.61	6.15	3.90	2.00	38.06
1878	0.56	1.52	3.63	3.44	4.20	3.48	5.75	1.99	0.78	6.03	0.78	1.48	33.64
1879	0.71	1.32	0.91	2.76	2.19	3.63	6.98	3.06	0.40	1.93	5.35	1.18	30.42
1880	3.17	1.92	2.70	4.53	4.11	3.88	1.74	2.98	3.51	1.20	1.73	0.60	32.07
1881	1.71	6.50	3.49	1.33	2.39	6.44	7.72	0.38	3.72	5.37	2.17	2.99	44.21
1882	1.19	2.01	3.54	5.15	3.42	5.69	2.96	3.82	0.93	3.32	2.24	2.49	36.76
1883	1.98	3.76	0.57	1.96	6.39	4.21	3.69	1.50	0.92	6.66	3.87	1.58	37.09
1884	1.42	1.91	2.88	3.45	3.43	6.16	6.13	3.68	3.85	6.24	1.99	6.51	47.65
1885	2.39	2.50	0.26	4.33	2.39	5.47	4.50	9.18	4.64	3.95	1.96	3.57	45.14
1886	5.88	3.40	4.55	4.36	4.93	2.74	0.35	8.41	2.25	4.03	1.61	1.65	44.16
1887	4.21	6.44	1.25	0.92	1.98	0.89	3.12	4.42	3.75	2.09	1.39	5.01	35.47
1888	1.72	1.30	3.03	2.54	6.25	1.27	4.90	1.99	1.05	1.80	2.39	2.58	30.82
1889	2.96	1.51	1.32	2.88	6.64	3.93	2.02	0.74	1.95	0.67	2.88	2.88	29.88
1890	2.81	2.69	2.42	3.76	5.28	12.33	0.83	3.33	0.60	5.98	2.28	1.60	43.91
1891	2.72	1.65	3.21	4.83	2.75	4.87	2.27	1.44	0.75	1.53	3.67	1.30	30.99
1892	3.72	1.95	1.61	4.71	9.18	14.16	4.32	7.26	1.61	0.78	2.53	2.96	54.79
1893	3.39	2.45	3.21	5.38	3.09	4.51	3.49	1.13	2.82	3.60	1.71	1.71	36.49
1894	1.47	2.06	3.26	2.74	3.51	2.03	1.48	1.27	5.15	1.81	1.79	0.33	26.90
1895	2.27	0.93	2.53	1.51	3.54	1.93	2.53	3.06	2.77	1.32	3.34	2.59	28.32
1896	0.90	2.40	2.02	4.08	6.31	2.34	4.36	3.75	8.33	0.85	3.05	0.90	39.29
1897	4.72	1.45	4.90	3.81	1.12	4.09	2.71	0.90	1.18	0.68	1.73	1.62	28.91
1898	2.97	2.52	4.21	2.16	4.36	2.79	2.32	5.46	3.49	2.74	1.23	0.84	35.09
1899	0.43	0.95	1.74	...	...	...	...	...	...	1.60	1.12	2.23	....
1900	...	3.39	1.07	2.90	3.46	2.58	4.04	5.35	2.98	3.64	1.93	0.48	....
1901	1.41	2.40	3.93	0.46	2.00	3.13	4.39	1.36	3.34	0.82	1.03	1.53	25.80
1902	0.48	1.63	3.17	1.62	7.88	7.45	6.87	1.49	7.04	2.07	2.94	1.87	44.51
1903	0.58	1.19	3.84	6.00	3.73	2.38	5.25	9.29	6.06	2.77	1.25	1.04	43.38
1904	2.90	1.30	4.43	2.84	3.36	1.24	3.15	3.35	3.52	1.89	0.02	1.93	29.93
1905	0.61	1.42	3.80	2.90	5.51	2.65	2.65	3.13	1.95	3.53	2.24	1.45	31.84
1906	2.60	1.64	2.88	1.47	3.07	3.11	2.99	6.91	4.51	1.83	2.56	1.74	35.31
1907	3.58	0.29	2.15	2.34	2.90	4.94	5.07	3.76	5.70	0.74	1.31	1.23	34.01
1908	0.63	2.09	4.17	3.59	7.84	2.31	3.08	2.34	0.94	1.07	2.82	0.56	31.44
1909	1.91	1.83	0.93	5.96	4.39	3.90	1.25	6.41	3.59	0.84	4.11	3.23	38.35
1910	1.54	0.52	0.27	3.84	4.25	0.63	2.04	3.58	2.66	0.84	1.14	0.57	21.88
1911	0.80	2.56	0.70	5.17	2.55	3.70	1.27	7.04	5.48	2.39	4.57	1.60	37.83
1912	0.22	1.06	1.70	2.87	3.33	3.85	5.84	6.61	3.86	4.65	1.23	1.45	36.67
1913	0.67	1.28	2.19	2.05	5.52	2.77	4.77	2.72	3.58	2.88	1.96	0.28	30.67
1914	1.27	1.15	4.11	1.32	6.05	7.37	0.84	2.25	3.92	1.75	0.56	2.16	32.75

From April, 1894, to December, 1894, inclusive, the values are for Winnebago. All other values prior to September, 1898, also the values for 1914, are for Rockford. The three stations are in the same county.

Riley, McHenry County, Illinois

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1869	...	...	...	...	4.74	7.38	2.30	4.59	0.98	0.97	2.39	2.60	....
1870	2.28	0.59	4.43	1.51	0.54	0.99	4.66	3.79	5.36	3.14	0.69	1.50	29.48
1871	2.82	1.30	2.23	2.05	2.32	5.17	1.04	3.07	0.68	2.97	2.25	1.93	27.83
1872	0.45	0.42	2.78	3.47	3.41	3.22	4.38	3.31	8.89	0.62	1.47	0.93	33.35
1873	2.14	0.32	1.56	2.40	5.23	2.59	2.61	1.98	2.34	2.21	1.55	3.42	28.35
1874	3.76	0.95	1.93	3.02	2.04	2.96	1.09	2.75	2.58	2.31	1.48	0.48	25.35
1875	1.38	1.95	1.01	2.33	3.28	5.26	4.24	2.14	7.29	2.76	0.72	2.32	34.68
1876	3.01	3.51	3.42	2.09	3.76	4.57	7.64	1.52	4.70	0.97	3.67	0.71	39.57
1877	1.72	0.03	6.50	2.81	0.93	4.83	1.96	3.60	0.21	6.57	2.90	3.38	35.44
1878	0.85	1.33	2.72	2.87	4.26	2.46	4.73	3.52	1.46	4.71	1.06	2.46	32.43
1879	0.85	1.54	1.15	2.30	4.97	4.81	5.39	1.96	1.20	1.38	5.30	1.47	32.32
1880	4.14	1.62	1.40	3.10	2.68	5.28	2.68	4.20	4.02	2.37	1.01	0.75	33.25
1881	1.54	5.28	6.48	0.98	3.10	5.62	5.38	1.01	5.47	6.81	2.86	2.69	47.22
1882	1.57	2.15	4.58	3.29	3.59	4.42	3.63	2.08	2.86	4.17	1.52	2.00	35.86
1883	2.18	4.61	0.89	2.00	6.18	3.92	2.94	1.17	2.04	4.28	4.03	1.67	35.91
1884	0.80	2.20	1.51	2.85	2.56	4.22	4.19	3.36	4.34	3.85	1.79	3.28	34.95
1885	2.32	1.92	0.29	3.97	1.72	5.80	2.07	6.80	3.86	2.57	2.09	2.37	35.78
1886	3.60	1.61	3.68	3.76	3.13	1.89	0.81	5.85	2.25	2.55	0.98	1.13	31.24
1887	3.59	4.32	1.01	1.55	0.95	1.23	2.70	4.85	4.61	2.75	1.87	3.81	33.24
1888	1.24	1.17	2.34	2.16	4.48	0.81	3.44	4.23	1.00	1.70	1.97	1.87	26.41
1889	1.86	1.21	1.56	2.48	4.09	3.25	3.44	0.77	1.68	0.40	2.34	1.44	24.52
1890	2.65	1.52	2.14	2.88	4.33	9.64	0.53	3.83	0.67	5.38	1.74	1.13	36.44
1891	2.22	1.65	1.64	4.05	4.38	5.06	2.40	1.95	0.87	1.16	3.75	2.16	31.29
1892	1.73	1.22	1.49	2.83	11.05	11.21	3.76	4.42	1.43	0.72	1.64	1.71	43.21
1893	1.57	1.55	1.82	3.71	2.99	5.13	2.32	0.45	4.18	2.47	2.34	1.42	29.95
1894	2.24	1.33	3.02	2.62	3.62	1.22	0.31	1.33	15.73	1.57	2.06	0.44	35.49
1895	2.09	0.46	1.32	1.81	2.91	1.68	3.43	3.94	2.16	0.41	2.69	3.00	25.90
1896	0.61	1.56	1.85	2.97	5.04	3.02	3.29	2.15	9.45	0.38	1.77	0.43	32.52
1897	4.45	1.49	3.87	2.59	1.08	3.23	1.57	1.24	1.15	0.48	2.52	1.50	25.17
1898	3.89	3.03	4.76	1.90	2.74	7.74	2.27	4.35	2.16	3.41	1.64	0.76	38.65
1899	0.44	1.21	1.65	0.76	4.61	2.56	4.04	2.06	1.59	1.72	1.44	1.56	23.64
1900	1.48	3.12	1.35	1.36	3.08	2.43	6.03	7.09	2.58	2.74	2.00	0.42	33.68
1901	1.38	1.69	3.38	0.26	1.10	2.37	3.23	1.15	2.01	0.86	1.05	1.22	19.70
1902	0.55	1.42	2.31	1.31	6.16	6.83	7.78	1.00	3.58	2.90	2.87	2.35	39.06
1903	0.80	1.33	3.47	3.36	3.29	1.65	4.61	6.52	6.43	1.97	0.82	1.66	35.91
1904	1.79	1.43	3.98	2.27	2.81	1.52	3.35	3.32	4.79	1.28	0.15	1.35	28.04
1905	0.82	1.69	2.73	3.31	7.46	6.32	3.30	5.85	2.38	3.89	1.57	1.40	40.72
1906	2.73	1.96	1.94	1.20	2.83	1.95	1.25	4.90	4.05	1.79	2.52	1.47	28.59
1907	3.67	0.38	1.68	3.09	4.29	4.84	4.92	3.55	4.90	0.50	1.20	1.16	34.18
1908	0.77	2.63	4.06	4.05	6.87	3.82	2.68	2.21	0.47	0.96	1.66	0.99	31.17
1909	2.50	2.58	1.10	7.70	1.62	3.37	0.63	6.25	3.37	0.72	3.91	5.05	38.80
1910	2.23	0.55	0.24	3.32	4.42	0.80	1.09	3.68	2.57	1.51	1.27	0.80	22.48
1911	0.96	2.10	0.68	3.83	2.64	3.17	1.21	7.35	4.40	2.16	4.70	1.70	34.90
1912	0.28	1.08	1.51	2.42	2.31	5.91	5.59	4.29	3.60	5.98	1.24	1.08	35.29
1913	1.02	1.65	2.45	2.12	5.63	2.04	6.55	3.69	3.09	3.22	1.73	0.55	33.74
1914	1.68	0.76	3.22	2.15	5.27	5.35	1.74	2.13	4.34	2.48	0.50	1.96	31.58
1915	1.48	1.69	0.84	0.47	5.99	4.51	5.36	1.12	4.71	1.11	2.67	0.54	30.49
1916	4.15	0.73	3.53	1.69	3.33	6.92	1.52	2.93	5.07	4.33	1.96	2.57	38.73

ROCKFORD, WINNEBAGO COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1874	4.87	0.83	1.01	1.23	1.09	3.39	0.90	1.19	5.97	1.10	1.73	0.59	23.90
1875	0.75	1.56	0.59	3.06	2.25	6.21	5.96	2.15	3.56	2.34	0.51	2.57	31.51
1876	3.46	2.91	2.84	3.33	6.06	4.25	5.80	2.42	4.71	1.50	4.87	0.41	42.56
1877	3.06	0.30	5.53	3.99	2.20	4.32	1.96	4.04	0.61	6.15	3.90	2.00	38.06
1878	0.56	1.52	3.63	3.44	4.20	3.48	5.75	1.99	0.78	6.03	0.78	1.48	33.64
1879	0.71	1.32	0.91	2.76	2.19	3.63	6.98	3.06	0.40	1.93	5.35	1.18	30.42
1880	3.17	1.92	2.70	4.53	4.11	3.88	1.74	2.98	3.51	1.20	1.73	0.60	32.07
1881	1.71	6.50	3.49	1.38	2.39	6.44	7.72	0.33	3.72	5.37	2.17	2.99	44.21
1882	1.19	2.01	3.54	5.15	3.42	5.69	2.96	3.82	0.93	3.32	2.24	2.49	36.76
1883	1.98	3.76	0.57	1.96	6.39	4.21	3.69	1.50	0.92	6.66	3.87	1.58	37.09
1884	1.42	1.92	2.88	3.45	3.43	6.16	6.13	3.68	3.85	6.24	1.99	6.51	47.66
1885	2.39	2.50	0.26	4.33	2.39	5.47	4.50	9.18	4.64	3.95	1.96	3.57	45.14
1886	5.87	3.40	4.55	4.36	4.93	2.74	0.35	8.41	2.25	4.03	1.61	1.65	44.15
1887	4.21	6.44	1.25	0.92	1.98	0.89	3.12	4.42	3.75	2.09	1.39	5.01	35.47
1888	1.72	1.30	3.03	2.54	6.25	1.27	4.90	1.99	1.05	1.80	2.39	2.58	30.82
1889	2.96	1.51	1.32	2.88	6.64	3.93	2.02	0.74	1.95	0.67	2.38	2.88	29.88
1890	2.81	2.69	2.42	3.76	5.28	12.33	0.83	3.33	0.60	5.98	2.28	1.60	43.91
1891	2.72	1.65	3.21	4.83	2.75	4.87	2.27	1.44	0.75	1.53	3.67	1.30	30.99
1892	3.72	1.95	1.61	4.71	9.18	14.16	4.32	7.26	1.61	0.78	2.53	2.96	54.79
1893	3.39	2.45	3.21	5.38	3.09	4.51	3.49	1.13	2.82	3.60	1.71	1.71	36.49
1894	....	....	....	....	....	....	....	....	....	....	....	....	.....
1895	2.27	0.93	2.53	1.51	3.54	1.93	2.53	3.06	2.77	1.32	3.34	2.59	28.32
1896	0.90	2.40	2.02	4.08	6.31	2.34	4.36	3.75	8.33	0.85	3.05	0.90	39.29
1897	4.72	1.45	4.90	3.81	1.12	4.09	2.71	0.90	1.18	0.68	1.73	1.62	28.91
1898	2.97	2.52	4.21	2.16	4.36	2.79	2.32	5.46	....	....	....	....	.....
1899	....	....	....	1.61	6.91	2.13	5.69	2.34	1.61	....	....	....	.....
1900	....	....	....	2.74	....	2.73	....	9.22	3.70	....	....	....	.....
1901	....	....	....	....	2.14	3.72	2.75	1.16	2.85	....	....	....	.....
1902	....	....	....	0.84	3.30	7.74	5.76	1.14	6.48	....	....	....	.....
1903	....	....	....	3.95	2.53	1.62	5.49	7.59	5.39	....	....	....	.....
1904	....	....	....	*2.20	*3.38	....	....	*4.06	*3.39	....	....	....	.....
1905	*0.63	*1.55	*3.78	2.70	6.13	3.55	*3.16	3.75	1.16	3.90	2.33	0.93	33.57
1906	3.29	2.28	3.35	1.49	2.42	4.37	3.91	3.23	4.69	2.19	3.39	1.70	36.31
1907	3.18	0.69	1.90	2.78	2.96	4.54	4.63	2.80	4.84	0.82	0.98	0.17	30.29
1908	1.32	2.40	4.54	3.34	6.58	3.23	3.67	1.87	0.92	0.89	2.39	0.79	31.94
1909	2.79	2.31	1.13	6.01	4.78	3.81	0.68	7.69	3.41	0.75	4.15	3.48	40.99
1910	2.06	0.80	0.27	3.50	4.76	0.72	1.91	3.66	2.12	1.03	1.44	0.60	22.87
1911	0.74	2.95	0.55	5.57	2.98	2.39	0.81	8.70	6.56	2.86	4.80	1.91	40.82
1912	0.62	1.82	1.56	2.55	3.94	3.78	8.21	5.56	3.53	4.98	1.34	1.14	39.03
1913	1.30	1.74	2.80	1.53	5.70	1.59	5.85	2.78	3.67	3.13	1.52	0.55	32.16
1914	1.27	1.15	4.11	1.32	6.05	7.37	0.84	2.25	3.92	1.75	0.56	2.16	32.75
1915	1.78	2.88	1.01	0.28	7.02	4.68	5.85	2.05	5.57	1.27	2.85	0.52	35.76
1916	4.33	0.81	3.45	1.34	4.58	7.81	0.48	1.98	7.00	4.25	1.66	1.72	39.41

*Estimated from surrounding stations.

WINNEBAGO, WINNEBAGO COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1857	....	....	3.26	2.39	3.64	3.34	4.01	6.10	2.56	4.76	1.91	1.80	.....
1858	2.37	1.29	2.08	3.98	6.87	7.45	3.36	2.85	5.59	2.94	4.50	1.88	45.16
1859	1.28	1.36	4.88	3.44	2.82	2.42	1.89	1.34	2.57	0.68	3.04	0.79	26.51
1860	1.14	2.00	0.78	1.19	4.28	4.47	....	2.26	5.48	2.17	2.44	3.80	.....
1861	2.66	4.87	2.41	4.98	5.39	1.33	5.78	3.05	6.89	3.56	1.75	1.84	44.51
1862	3.78	1.02	2.16	5.59	3.67	3.09	....	6.98	5.96	2.76	0.98	1.52	.....
1863	2.86	....	1.65	....	5.05	1.67	2.10	2.24	1.63	3.49	2.22	3.62	.....
1864	2.05	0.30	2.71	2.66	1.46	1.13	5.83	1.88	3.57	2.28	2.27	2.76	28.90
1865	0.27	3.25	3.58	4.33	1.56	4.66	6.17	7.22	9.09	3.58	0.42	0.74	44.82
1866	2.49	0.98	2.00	3.06	1.90	4.45	5.03	7.52	4.19	2.86	0.59	3.84	38.91
1867	2.86	2.88	1.58	1.48	4.65	3.74	1.58	3.33	1.58	0.50	1.68	1.08	26.74
1868	0.82	0.77	4.98	4.43	3.82	5.12	2.93	1.60	5.23	1.00	3.31	1.30	35.31
1869	1.39	2.14	0.95	2.76	5.53	7.01	2.91	4.22	3.85	0.83	2.76	2.86	37.21
1870	2.87	0.75	3.41	1.32	1.25	2.12	3.74	3.66	3.92	2.75	0.60	0.78	27.17
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1888	†1.72	†1.30	†3.03	2.20	5.69	1.13	7.63	2.27	1.18	1.75	2.17	2.65	32.72
1889	2.18	2.00	1.40	4.14	5.42	3.20	2.77	0.10	1.66	0.62	1.73	2.83	28.05
1890	3.39	2.73	1.64	3.50	4.35	10.15	0.40	2.55	0.50	6.40	2.10	1.40	39.11
1891	2.30	1.55	4.25	4.17	2.50	3.45	2.13	1.24	0.99	1.49	3.71	2.26	30.04
1892	2.60	1.76	1.95	4.40	8.33	10.29	3.85	5.15	1.74	0.50	2.12	2.38	45.07
1893	2.04	2.04	2.30	4.66	2.72	3.26	2.61	0.80	2.68	2.45	1.67	1.29	28.52
1894	1.48	1.25	3.55	2.74	3.51	2.03	1.48	1.27	5.15	1.81	1.79	0.83	26.89
1895	1.42	0.39	1.90	0.70	4.07	1.89	3.89	2.92	2.29	0.80	3.07	2.07	25.41
1896	0.65	1.54	1.28	3.63	6.50	2.94	4.95	1.92	5.61	0.75	2.18	0.58	32.53
1897	3.74	1.38	4.87	3.63	1.31	4.70	3.82	1.37	1.01	0.58	1.28	1.58	29.27
1898	2.95	3.07	3.95	3.39	3.52	3.65	2.74	7.13	2.47	3.80	1.81	0.71	39.19
1899	0.53	1.49	1.87	2.14	6.56	2.15	6.18	2.57	1.68	2.22	1.52	1.98	30.89
1900	2.20	3.22	2.07	2.98	4.96	2.67	5.81	5.88	3.58	3.70	2.10	0.57	39.74
1901	1.10	1.47	3.52	0.48	2.79	2.83	3.76	1.21	3.15	0.92	1.20	2.05	24.48
1902	0.63	1.43	2.86	1.74	7.62	8.76	5.85	1.53	4.71	1.62	3.06	2.10	41.91
1903	0.58	1.81	3.51	4.91	3.73	2.75	4.93	7.66	5.49	4.35	1.15	1.68	42.55
1904	1.74	1.38	4.55	3.41	3.17	1.53	3.41	2.95	4.11	1.95	0.13	3.34	31.67
1905	0.66	1.69	3.77	3.59	6.38	3.76	3.67	3.83	0.77	4.10	2.29	1.48	35.99
1906	3.72	2.17	3.24	2.09	4.05	4.93	2.83	6.02	4.68	2.56	2.85	1.59	40.73
1907	3.68	0.76	1.49	3.46	3.20	5.81	6.65	4.09	6.45	0.71	1.45	1.77	39.52
1908	1.00	2.57	5.41	4.48	8.17	3.51	4.59	2.85	1.15	1.02	3.66	0.85	39.26
1909	2.52	2.63	1.41	7.75	3.47	4.52	1.03	6.82	2.18	1.11	4.00	4.82	41.76
1910	2.41	0.69	0.36	4.56	4.73	1.01	2.32	3.70	2.61	0.78	1.90	0.91	25.98
1911	0.91	3.13	0.61	5.42	2.75	3.20	1.09	7.58	7.57	3.32	4.65	2.10	42.33
1912	0.44	1.34	2.07	2.50	3.53	3.36	6.81	8.11	4.00	4.59	1.83	1.60	40.18
1913	1.12	1.44	3.48	1.96	6.06	3.20	4.89	5.15	2.76	3.32	1.90	0.30	35.58
1914	1.27	1.15	4.11	1.32	6.05	7.37	0.84	2.25	3.92	1.75	0.56	2.16	32.75

†Values are for Rockford, in the same county.
Values for 1914 are for Rockford, in the same county.

PRECIPITATION FOR EXTREME NORTHERN DISTRICT
AVERAGE OF ALL STATIONS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1857	...	...	3.26	2.39	3.64	3.84	4.01	6.10	2.56	4.76	1.91	1.80	....
1858	2.87	1.29	2.08	3.98	6.87	7.45	3.36	2.85	5.59	2.94	4.50	1.88	45.16
1859	1.28	1.36	4.88	3.44	2.82	2.42	1.89	1.84	2.57	0.68	3.04	0.79	26.51
1860	1.14	2.00	0.78	1.19	4.28	4.47	...	2.26	5.48	2.17	2.44	3.30	....
1861	2.66	4.87	2.41	4.98	5.39	1.33	5.78	3.05	6.89	3.56	1.75	1.84	44.51
1862	3.78	1.02	2.16	5.59	3.67	3.09	...	6.98	5.96	2.76	0.98	1.52	....
1863	2.86	...	1.65	...	5.05	1.67	2.10	2.24	1.63	3.49	2.22	3.62	....
1864	2.05	0.30	2.71	2.66	1.46	1.13	5.88	1.88	3.57	2.28	2.27	2.76	28.90
1865	0.27	3.25	3.58	4.33	1.56	4.66	6.17	7.22	9.09	3.53	0.42	0.74	44.82
1866	2.49	0.98	2.00	3.06	1.90	4.45	5.08	7.52	4.19	2.86	0.59	3.84	38.91
1867	2.86	2.88	1.58	1.48	4.65	3.74	1.58	3.33	1.53	0.50	1.68	1.08	26.74
1868	0.82	0.77	4.98	4.43	3.82	5.12	2.93	1.60	5.23	1.00	3.31	1.80	35.81
1869	1.39	2.14	0.95	2.76	5.13	7.19	2.60	4.40	2.41	0.90	2.57	2.78	35.17
1870	2.57	0.67	3.92	1.41	0.89	1.55	4.20	3.72	4.64	2.94	0.64	1.14	28.29
1871	2.82	1.30	2.23	2.05	2.32	5.17	1.04	3.07	0.68	2.97	2.25	1.93	27.83
1872	0.45	0.42	2.78	3.47	3.41	3.22	4.38	3.31	8.89	0.62	1.47	0.84	33.26
1873	1.97	0.32	1.56	1.95	4.99	2.79	1.83	3.17	1.81	2.38	1.31	2.58	26.61
1874	3.99	0.78	1.31	1.75	1.32	3.26	1.53	1.81	5.55	1.67	2.48	0.57	25.97
1875	0.97	1.80	0.91	2.79	2.85	5.61	5.48	1.88	5.38	2.54	0.55	2.54	33.30
1876	3.28	2.71	3.28	3.34	5.46	5.24	6.85	3.07	5.00	1.27	3.72	0.51	43.73
1877	2.20	0.22	5.52	3.68	2.29	5.06	2.20	3.91	0.52	6.06	3.50	2.52	37.68
1878	0.61	1.58	3.10	3.52	4.32	3.44	5.73	2.30	2.49	4.90	0.86	1.63	34.48
1879	0.68	1.30	1.04	2.46	3.07	4.27	6.53	2.68	1.25	1.54	5.35	1.28	31.40
1880	3.11	1.62	2.34	3.92	3.66	4.77	2.43	4.33	4.47	1.36	1.64	0.80	34.45
1881	1.71	5.51	4.31	1.26	2.52	6.51	7.96	1.03	5.79	6.06	2.47	2.56	47.69
1882	1.20	1.69	3.29	4.51	3.65	5.52	2.76	3.00	1.70	4.02	1.89	2.19	35.42
1883	1.93	3.68	0.59	1.96	6.52	4.42	4.56	1.72	1.49	5.51	3.36	1.68	37.42
1884	1.16	2.06	2.53	3.18	3.53	5.36	5.44	3.74	4.03	5.12	1.80	5.10	43.05
1885	2.22	1.91	0.30	4.08	2.28	5.72	4.36	8.30	4.43	3.20	1.66	3.16	41.62
1886	4.63	2.44	4.28	3.65	4.29	2.02	0.60	5.83	2.46	3.67	1.52	1.37	36.76
1887	3.83	5.31	1.33	1.19	1.86	1.08	2.84	4.52	4.93	2.29	1.35	4.10	34.63
1888	1.52	1.28	2.97	2.40	5.70	1.95	4.39	2.44	1.26	1.73	2.33	2.83	30.80
1889	2.30	1.51	1.18	3.19	5.36	3.63	2.89	0.52	1.76	0.60	2.08	2.28	27.30
1890	2.79	2.18	2.06	3.87	4.92	10.81	0.76	3.83	1.22	6.03	2.03	1.31	41.81
1891	2.25	1.50	3.00	3.90	2.98	4.12	2.78	1.88	0.81	1.58	3.61	1.82	30.18
1892	2.82	1.58	1.71	4.20	9.38	12.79	4.27	5.82	2.04	0.64	2.14	2.42	49.31
1893	2.40	1.96	2.61	4.69	2.99	4.58	3.10	0.82	3.16	2.76	1.89	1.49	32.45
1894	1.57	1.46	3.22	2.59	3.10	1.38	0.82	1.30	7.25	1.68	1.79	0.86	27.02
1895	1.90	0.67	1.85	1.20	3.34	1.70	3.08	2.95	2.41	0.93	2.91	2.60	25.54
1896	0.76	1.97	1.59	4.51	6.36	2.75	4.94	2.72	7.48	1.08	2.33	0.70	37.19
1897	4.04	1.44	4.30	3.45	1.34	3.69	3.03	1.18	1.54	0.69	1.70	1.68	28.08
1898	2.99	2.63	3.98	2.73	3.89	4.27	2.50	5.35	2.80	3.45	1.46	0.66	36.71
1899	0.48	1.08	1.69	2.19	5.96	2.73	5.01	2.23	1.47	1.79	1.26	1.90	27.79
1900	1.61	2.96	1.58	2.47	4.06	2.49	5.97	6.18	3.24	3.11	1.92	0.47	36.06
1901	1.24	1.66	3.43	0.54	2.23	2.66	3.21	1.07	2.84	0.97	0.92	1.43	22.20
1902	0.57	1.46	2.41	1.32	7.68	7.27	6.55	1.21	5.51	2.50	2.31	1.85	40.64
1903	0.50	1.22	3.05	4.01	3.53	2.24	5.66	7.38	5.49	2.32	0.93	1.27	37.60
1904	1.50	1.19	4.20	2.50	3.08	1.28	3.24	3.08	3.76	1.90	0.28	2.06	28.02
1905	0.78	1.66	3.17	3.11	5.66	3.93	3.35	4.14	1.72	3.86	2.13	1.33	34.84
1906	3.04	1.90	2.39	1.56	3.01	3.44	2.37	5.14	4.26	2.05	2.93	1.61	33.70
1907	3.27	0.49	1.64	2.52	3.55	4.33	4.74	4.00	5.55	0.76	1.35	1.18	33.38
1908	1.16	2.29	3.87	3.80	6.76	3.11	3.39	2.29	0.94	1.05	2.43	0.80	31.89
1909	2.32	2.04	0.97	7.25	2.94	4.03	1.01	5.87	3.41	1.01	3.72	3.61	38.18
1910	2.15	0.62	0.22	3.59	4.42	1.15	1.44	3.70	2.64	1.24	1.38	0.76	23.31
1911	0.82	2.95	0.55	4.79	2.81	3.21	1.68	7.52	5.62	2.87	4.43	1.96	39.21
1912	0.44	1.23	1.77	2.59	3.79	3.47	6.66	5.62	3.61	4.89	1.48	1.26	36.81
1913	1.17	1.37	2.71	1.95	6.10	2.26	4.64	3.29	3.30	3.49	1.66	0.34	32.28
1914	1.48	1.11	3.33	1.58	5.80	6.35	1.53	2.46	4.14	2.35	0.50	2.16	32.79
1915	1.75	2.36	1.18	0.44	7.14	4.03	5.12	2.12	6.96	1.61	2.38	0.46	35.55
1916	3.76	0.93	3.63	1.91	3.47	6.75	1.22	2.09	5.51	4.04	1.72	1.75	36.78

PRECIPITATION FOR CENTRAL-NORTHERN DISTRICT BY STATIONS

ALEDO, MERCER COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1900	....	....	....	....	....	....	....	....	....	....	....	0.35	.....
1901	1.44	1.88	2.72	1.28	1.98	2.28	2.16	0.44	2.36	0.87	1.06	0.91	19.33
1902	0.58	0.82	2.57	3.89	5.36	7.81	8.79	6.89	5.11	8.51	2.10	1.96	48.89
1903	0.78	1.58	1.86	3.60	6.26	3.84	1.89	6.53	6.35	5.09	0.98	0.66	39.32
1904	1.84	0.37	2.78	1.95	8.33	2.08	4.49	7.58	8.62	0.62	0.15	1.75	30.51
1905	0.58	1.52	2.06	3.72	3.24	4.52	2.46	2.14	1.70	2.88	2.05	1.29	27.61
1906	2.57	2.28	2.42	2.40	4.87	4.91	1.18	3.20	5.68	1.57	3.12	1.67	35.32
1907	4.10	0.26	2.87	2.27	5.13	2.66	6.74	5.60	2.02	0.62	1.40	0.54	34.21
1908	0.47	2.58	1.85	2.20	6.88	4.93	3.98	5.73	1.92	1.40	2.63	0.72	35.29
1909	1.32	2.34	1.61	4.00	4.19	3.86	4.10	0.44	8.04	2.28	4.79	3.66	35.08
1910	1.79	0.98	0.70	3.62	4.37	2.82	2.15	2.73	2.95	0.87	0.42	0.95	24.35
1911	1.52	2.99	1.37	8.29	1.98	1.30	3.84	1.85	13.44	2.50	4.06	1.90	40.04
1912	0.17	1.08	1.55	2.95	1.78	2.09	4.47	1.40	1.77	4.71	0.88	0.74	28.59
1913	1.09	1.77	2.87	2.14	5.62	5.61	0.10	2.49	2.19	2.81	1.24	0.88	28.76
1914	1.10	0.76	2.36	1.00	2.62	4.87	0.67	1.48	7.01	2.81	0.38	1.76	26.82
1915	1.53	2.17	0.59	0.72	6.62	2.66	7.30	1.59	6.78	0.67	3.45	0.99	35.02
1916	4.71	0.22	2.68	2.59	6.87	5.11	0.49	1.11	3.20	8.65	1.51	1,41	88.00

AURORA, KANE COUNTY, ILLINOIS

1857	....	....	....	....	....	....	....	....	....	4.40	2.57	1.00	.....
1858	2.19	1.34	2.38	5.19	6.83	5.07	5.69	3.84	5.01	3.91	3.64	2.41	47.50
1859	1.82	1.22	6.00	2.90	2.69	2.88	2.02	2.52	3.06	1.53	3.08	0.75	30.47
1860	....	1.62	0.66	2.28	4.57	3.18	6.10	1.67	3.01	....	....	2.95	.....
1861	1.05	2.40	....	....	....	....	....	....	....	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1865	....	....	....	....	....	....	....	....	....	....	0.57	0.60	.....
1866	1.97	0.77	2.01	0.95	1.67	2.32	3.21	6.02	4.80	2.50	0.94	3.08	30.24
1867	2.45	3.30	1.49	2.39	5.24	3.41	2.98	2.79	2.54	1.21	2.17	1.29	31.26
1868	0.90	1.05	6.86	4.91	2.55	3.00	2.28	4.50	5.47	2.07	2.55	....	.....
1869	....	....	....	....	....	....	....	....	....	....	....	3.68	.....
1870	5.48	2.45	1.92	1.58	1.35	1.63	5.50	3.31	3.63	4.63	1.51	1.87	34.36
1871	....	1.80	3.04	2.33	4.48	4.75	1.75	1.97	0.78	3.41	2.58	2.21	.....
1872	0.35	0.65	2.76	....	....	....	....	....	6.20	0.90	1.18	0.70	.....
1878	5.34	0.57	1.50	3.93	3.28	2.20	5.43	3.61	....	2.50	1.30	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1879	....	....	....	....	....	....	0.88	1.56	0.76	2.40	4.17	1.70	.....
1880	4.08	3.55	2.25	4.36	6.10	3.91	5.63	7.46	8.22	2.14	1.03	0.76	44.49
1881	1.17	3.06	3.88	1.68	2.61	5.80	3.19	0.73	3.24	7.15	4.97	3.27	45.75
1882	1.14	2.95	2.83	5.98	5.04	†7.33	†3.89	4.70	1.39	3.21	2.10	2.47	43.03
1883	2.63	7.27	0.61	3.75	7.23	3.56	4.44	0.95	1.57	6.34	5.55	2.61	46.51
1884	1.24	3.74	2.30	2.66	2.26	2.18	6.38	2.48	2.42	4.61	1.90	4.59	36.76
1885	2.31	2.09	0.38	3.31	3.16	5.07	2.59	7.72	4.04	3.74	2.04	3.05	39.50
1886	3.63	1.76	3.00	4.24	5.39	1.27	0.36	2.97	5.60	1.80	1.26	1.18	32.46
1887	4.36	5.86	1.06	0.82	3.02	0.58	2.34	3.79	4.33	3.54	2.21	4.25	36.16
1888	1.40	1.56	3.19	2.08	5.16	0.98	3.20	5.66	1.89	3.10	3.27	2.61	34.10
1889	2.06	1.32	1.47	2.63	3.82	4.38	5.08	†1.21	3.82	1.11	2.87	2.53	32.30
1890	3.24	1.18	2.64	2.17	4.25	6.97	0.78	2.38	1.90	4.53	1.79	0.78	32.61
1891	2.35	2.28	2.57	3.94	2.14	3.24	2.35	5.01	0.66	0.68	4.21	1.66	31.09
1892	1.53	1.18	2.28	3.59	8.29	12.83	4.48	2.74	2.36	1.28	1.63	2.26	44.45
1898	1.36	2.25	2.69	4.65	2.10	3.05	1.19	0.32	2.70	3.20	2.99	2.60	29.10
1894	2.96	1.95	3.17	2.49	2.76	1.87	0.62	1.79	7.07	1.68	1.93	0.96	29.25
1895	1.53	0.50	1.14	1.48	3.34	1.66	3.83	4.80	1.17	1.11	5.41	5.89	31.86

†Interpolated from surrounding stations.

PRECIPITATION FOR EXTREME NORTHERN DISTRICT
AVERAGE OF ALL STATIONS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1857	...	...	3.26	2.89	3.64	3.84	4.01	6.10	2.56	4.76	1.91	1.30	....
1858	2.37	1.29	2.08	3.98	6.87	7.45	3.36	2.85	5.59	2.94	4.50	1.88	45.16
1859	1.28	1.36	4.88	3.44	2.82	2.42	1.89	1.84	2.57	0.68	3.04	0.79	26.51
1860	1.14	2.00	0.78	1.19	4.28	4.47	...	2.26	5.48	2.17	2.44	3.30	....
1861	2.66	4.87	2.41	4.98	5.39	1.88	5.78	3.05	6.89	3.56	1.75	1.84	44.51
1862	3.78	1.02	2.16	5.59	3.67	3.09	...	6.98	5.96	2.76	0.98	1.52	....
1863	2.86	...	1.65	...	5.05	1.67	2.10	2.24	1.63	3.49	2.22	3.62	....
1864	2.05	0.80	2.71	2.66	1.46	1.13	5.83	1.88	3.57	2.28	2.27	2.76	28.90
1865	0.27	3.25	3.58	4.33	1.56	4.66	6.17	7.22	9.09	3.53	0.42	0.74	44.82
1866	2.49	0.98	2.00	3.06	1.90	4.45	5.08	7.52	4.19	2.86	0.59	3.84	38.91
1867	2.86	2.88	1.58	1.43	4.65	3.74	1.58	3.33	1.53	0.50	1.68	1.03	26.74
1868	0.82	0.77	4.98	4.43	3.82	5.12	2.98	1.60	5.28	1.00	3.81	1.30	35.81
1869	1.39	2.14	0.95	2.76	5.18	7.19	2.60	4.40	2.41	0.90	2.57	2.78	35.17
1870	2.57	0.67	3.92	1.41	0.89	1.55	4.20	3.72	4.64	2.94	0.64	1.14	28.29
1871	2.82	1.30	2.23	2.05	2.32	5.17	1.04	3.07	0.68	2.97	2.25	1.93	27.83
1872	0.45	0.42	2.78	3.47	3.41	3.22	4.38	3.31	3.89	0.62	1.47	0.84	33.26
1873	1.97	0.82	1.56	1.95	4.99	2.79	1.83	3.17	1.81	2.38	1.31	2.58	26.61
1874	3.99	0.78	1.31	1.75	1.32	3.26	1.53	1.81	5.55	1.67	2.43	0.57	25.97
1875	0.97	1.80	0.91	2.79	2.85	5.61	5.48	1.88	5.38	2.54	0.55	2.54	33.30
1876	3.28	2.71	3.28	3.84	5.46	5.24	6.85	3.07	5.00	1.27	3.72	0.51	43.73
1877	2.20	0.22	5.52	3.68	2.29	5.06	2.20	3.91	0.52	6.06	3.50	2.52	37.63
1878	0.61	1.58	3.10	3.52	4.32	3.44	5.73	2.30	2.49	4.90	0.86	1.68	34.48
1879	0.68	1.30	1.04	2.46	3.07	4.27	6.53	2.63	1.25	1.54	5.35	1.28	31.40
1880	3.11	1.62	2.34	3.92	3.66	4.77	2.43	4.33	4.47	1.86	1.64	0.80	34.45
1881	1.71	5.51	4.31	1.26	2.53	6.51	7.96	1.03	5.79	6.06	2.47	2.56	47.69
1882	1.20	1.69	3.29	4.51	3.65	5.52	2.76	3.00	1.70	4.02	1.89	2.19	35.42
1883	1.93	3.68	0.59	1.96	6.53	4.42	4.56	1.72	1.49	5.51	3.86	1.68	37.42
1884	1.16	2.06	2.53	3.13	3.58	5.36	5.44	3.74	4.03	5.12	1.80	5.10	43.05
1885	2.22	1.91	0.80	4.08	2.28	5.72	4.36	3.30	4.43	3.20	1.66	3.16	41.62
1886	4.63	2.44	4.28	3.65	4.29	2.02	0.60	5.83	2.46	3.67	1.52	1.37	36.76
1887	3.83	5.31	1.33	1.19	1.86	1.08	2.84	4.52	4.98	2.29	1.35	4.10	34.63
1888	1.52	1.28	2.97	2.40	5.70	1.95	4.89	2.44	1.26	1.78	2.88	2.38	30.80
1889	2.30	1.51	1.18	3.19	5.36	3.68	2.89	0.52	1.76	0.60	2.08	2.28	27.30
1890	2.79	2.18	2.06	3.37	4.92	10.81	0.76	3.83	1.22	6.08	2.08	1.31	41.31
1891	2.25	1.50	3.00	3.90	2.98	4.12	2.73	1.88	0.81	1.58	3.61	1.82	30.18
1892	2.82	1.58	1.71	4.20	9.38	12.79	4.27	5.32	2.04	0.64	2.14	2.42	49.31
1893	2.40	1.96	2.61	4.69	2.99	4.58	3.10	0.82	3.16	2.76	1.89	1.49	32.45
1894	1.57	1.46	3.22	2.59	3.10	1.88	0.82	1.30	7.25	1.68	1.79	0.86	27.02
1895	1.90	0.67	1.85	1.20	3.34	1.70	3.08	2.95	2.41	0.93	2.91	2.60	25.54
1896	0.76	1.97	1.59	4.51	6.36	2.75	4.94	2.72	7.48	1.08	2.33	0.70	37.19
1897	4.04	1.44	4.30	3.45	1.34	3.69	3.03	1.18	1.54	0.69	1.70	1.68	28.08
1898	2.99	2.68	3.98	2.78	3.89	4.27	2.50	5.35	2.80	3.45	1.46	0.66	36.71
1899	0.48	1.08	1.69	2.19	5.96	2.73	5.01	2.23	1.47	1.79	1.26	1.90	27.79
1900	1.61	2.96	1.58	2.47	4.06	2.49	5.97	6.18	3.24	3.11	1.92	0.47	36.06
1901	1.24	1.66	3.43	0.54	2.23	2.66	3.21	1.07	2.84	0.97	0.92	1.43	22.20
1902	0.57	1.46	2.41	1.32	7.68	7.27	6.55	1.21	5.51	2.50	2.31	1.35	40.64
1903	0.50	1.22	3.05	4.01	3.53	2.24	5.66	7.38	5.49	2.82	0.93	1.27	37.60
1904	1.50	1.19	4.20	2.50	3.08	1.28	3.24	3.08	3.76	1.90	0.23	2.06	28.02
1905	0.78	1.66	3.17	3.11	5.66	3.93	3.35	4.14	1.72	3.86	2.13	1.33	34.84
1906	3.04	1.90	2.39	1.56	3.01	3.44	2.37	5.14	4.26	2.05	2.93	1.61	33.70
1907	3.27	0.49	1.64	2.52	3.55	4.83	4.74	4.00	5.55	0.76	1.35	1.18	33.88
1908	1.16	2.29	3.87	3.80	6.76	3.11	3.39	2.29	0.94	1.05	2.48	0.80	31.89
1909	2.32	2.04	0.97	7.25	2.94	4.03	1.01	5.87	3.41	1.01	3.72	3.61	38.18
1910	2.15	0.62	0.22	3.59	4.42	1.15	1.44	3.70	2.64	1.24	1.38	0.76	23.31
1911	0.82	2.95	0.55	4.79	2.81	3.21	1.68	7.52	5.62	2.87	4.43	1.96	39.21
1912	0.44	1.23	1.77	2.59	3.79	3.47	6.66	5.62	3.61	4.89	1.48	1.26	36.81
1913	1.17	1.37	2.71	1.95	6.10	2.26	4.64	3.29	3.30	3.49	1.66	0.34	32.28
1914	1.48	1.11	3.33	1.58	5.80	6.35	1.53	2.46	4.14	2.85	0.50	2.16	32.79
1915	1.75	2.36	1.18	0.44	7.14	4.03	5.12	2.12	6.96	1.61	2.38	0.46	35.55
1916	3.76	0.93	3.63	1.91	3.47	6.75	1.22	2.09	5.51	4.04	1.72	1.75	36.78

PRECIPITATION FOR CENTRAL-NORTHERN DISTRICT BY STATIONS

ALEDO, MERCER COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1900	....	....	....	....	....	....	....	....	....	....	....	0.35	.....
1901	1.44	1.88	2.72	1.28	1.93	2.28	2.16	0.44	2.36	0.87	1.06	0.91	19.33
1902	0.58	0.82	2.57	3.39	5.36	7.81	8.79	6.89	5.11	3.51	2.10	1.96	48.89
1903	0.73	1.53	1.86	3.60	6.26	3.84	1.89	6.53	6.35	5.09	0.98	0.66	39.32
1904	1.84	0.37	2.78	1.95	3.33	2.03	4.49	7.58	3.62	0.62	0.15	1.75	30.51
1905	0.58	1.52	2.06	3.72	3.24	4.52	2.46	2.14	1.70	2.33	2.05	1.29	27.61
1906	2.57	2.28	2.42	2.40	4.37	4.91	1.18	3.20	5.63	1.57	3.12	1.67	35.32
1907	4.10	0.26	2.87	2.27	5.13	2.66	6.74	5.60	2.02	0.62	1.40	0.54	34.21
1908	0.47	2.58	1.85	2.20	6.88	4.93	3.98	5.73	1.92	1.40	2.63	0.72	35.29
1909	1.32	2.34	1.61	4.00	4.19	3.36	4.10	0.44	3.04	2.28	4.79	3.66	35.08
1910	1.79	0.98	0.70	3.62	4.37	2.82	2.15	2.73	2.95	0.87	0.42	0.95	24.35
1911	1.52	2.99	1.37	3.29	1.98	1.30	3.84	1.85	13.44	2.50	4.06	1.90	40.04
1912	0.17	1.08	1.55	2.95	1.78	2.09	4.47	1.40	1.77	4.71	0.88	0.74	23.59
1913	1.09	1.77	2.87	2.14	5.62	5.61	0.10	2.49	2.19	2.81	1.24	0.83	28.76
1914	1.10	0.76	2.36	1.00	2.62	4.87	0.67	1.48	7.01	2.81	0.38	1.76	26.82
1915	1.53	2.17	0.59	0.72	6.62	2.66	7.30	1.59	6.73	0.67	3.45	0.99	35.02
1916	4.71	0.22	2.63	2.59	6.37	5.11	0.49	1.11	3.20	3.65	1.51	1,41	33.00

AURORA, KANE COUNTY, ILLINOIS

1857	....	....	....	....	....	....	....	....	....	4.40	2.57	1.00	.....
1858	2.19	1.34	2.38	5.19	6.83	5.07	5.69	3.84	5.01	3.91	3.64	2.41	47.50
1859	1.82	1.22	6.00	2.90	2.69	2.88	2.02	2.52	3.06	1.53	3.08	0.75	30.47
1860	....	1.62	0.66	2.28	4.57	3.13	6.10	1.67	3.01	....	....	2.95	.....
1861	1.05	2.40	....	....	....	....	....	....	....	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1865	....	....	....	....	....	....	....	....	....	....	0.57	0.60	.....
1866	1.97	0.77	2.01	0.95	1.67	2.32	3.21	6.02	4.80	2.50	0.94	3.08	30.24
1867	2.45	3.30	1.49	2.39	5.24	3.41	2.98	2.79	2.54	1.21	2.17	1.29	31.26
1868	0.90	1.05	6.86	4.91	2.55	3.00	2.28	4.50	5.47	2.07	2.55	....	.....
1869	....	....	....	....	....	....	....	....	....	....	....	3.63	.....
1870	5.48	2.45	1.92	1.58	1.35	1.63	5.50	3.31	3.63	4.63	1.51	1.37	34.36
1871	....	1.80	3.04	2.33	4.48	4.75	1.75	1.97	0.73	3.41	2.58	2.21	.....
1872	0.85	0.65	2.76	....	....	....	....	....	6.20	0.90	1.18	0.70	.....
1873	5.34	0.57	1.50	3.93	3.23	2.20	5.43	3.61	....	2.50	1.30	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1879	....	....	....	....	....	....	0.38	1.56	0.76	2.40	4.17	1.70	.....
1880	4.08	3.55	2.25	4.36	6.10	3.91	5.63	7.46	3.22	2.14	1.03	0.76	44.49
1881	1.17	8.06	3.88	1.68	2.61	5.80	3.19	0.73	3.24	7.15	4.97	3.27	45.75
1882	1.14	2.95	2.83	5.98	5.04	†7.33	†3.89	4.70	1.39	3.21	2.10	2.47	43.03
1883	2.63	7.27	0.61	3.75	7.23	3.56	4.44	0.95	1.57	6.34	5.55	2.61	46.51
1884	1.24	3.74	2.30	2.66	2.26	2.18	6.38	2.48	2.42	4.61	1.90	4.59	36.76
1885	2.31	2.09	0.38	3.31	3.16	5.07	2.59	7.72	4.04	3.74	2.04	3.05	39.50
1886	3.63	1.76	3.00	4.24	5.39	1.27	0.36	2.97	5.60	1.80	1.26	1.18	32.46
1887	4.36	5.86	1.06	0.82	3.02	0.58	2.34	3.79	4.33	3.54	2.21	4.25	36.16
1888	1.40	1.56	3.19	2.08	5.16	0.98	3.20	5.66	1.89	3.10	3.27	2.61	34.10
1889	2.06	1.32	1.47	2.63	3.82	4.38	5.08	†1.21	3.82	1.11	2.87	2.53	32.30
1890	3.24	1.18	2.64	2.17	4.25	6.97	0.78	2.38	1.90	4.53	1.79	0.78	32.61
1891	2.35	2.28	2.57	3.94	2.14	3.24	2.35	5.01	0.66	0.68	4.21	1.66	31.09
1892	1.53	1.18	2.28	3.59	8.29	12.83	4.48	2.74	2.36	1.28	1.63	2.26	44.45
1893	1.36	2.25	2.69	4.65	2.10	3.05	1.19	0.32	2.70	3.20	2.99	2.60	29.10
1894	2.96	1.95	3.17	2.49	2.76	1.87	0.62	1.79	7.07	1.68	1.98	0.96	29.25
1895	1.53	0.50	1.14	1.48	3.34	1.66	3.33	4.80	1.17	1.11	5.41	5.89	31.86

†Interpolated from surrounding stations.

AURORA, KANE COUNTY—*Concluded*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1896	0.91	1.91	1.75	3.75	6.12	2.06	5.60	2.43	6.92	0.22	3.83	0.16	35.66
1897	6.02	1.73	3.58	3.04	1.06	5.25	4.45	2.23	0.85	0.21	3.89	1.32	33.63
1898	4.26	3.21	5.09	1.30	4.43	5.39	1.07	4.22	4.25	4.66	2.60	1.66	42.14
1899	0.55	1.75	2.92	0.49	7.34	1.59	4.82	1.84	2.23	2.13	1.05	1.61	28.32
1900	1.68	3.72	2.23	0.78	4.17	2.94	3.55	3.23	1.99	2.83	3.28	0.41	30.81
1901	1.39	1.73	4.11	0.39	0.71	1.81	4.79	1.06	2.34	1.27	1.21	1.40	22.21
1902	0.47	2.05	3.14	2.16	6.18	13.19	7.43	2.32	7.29	2.02	2.93	1.71	50.89
1903	0.83	1.94	3.94	4.23	3.11	4.09	5.59	5.39	7.45	2.69	0.54	1.74	41.54
1904	2.12	1.47	5.02	4.21	2.51	1.96	3.81	5.62	5.05	1.53	0.06	1.69	35.05
1905	0.93	1.33	2.33	3.85	5.94	6.16	2.72	4.00	2.36	2.32	2.21	1.35	35.50
1906	3.10	2.52	2.12	1.57	3.10	1.67	2.12	3.80	8.31	2.25	2.64	2.48	35.68
1907	3.69	0.26	3.17	2.00	4.90	3.70	5.51	6.72	6.08	1.43	1.62	1.07	40.15
1908	0.81	3.86	3.58	3.10	7.19	1.43	4.50	5.35	0.95	0.67	2.02	0.97	34.43
1909	1.43	2.57	1.84	6.88	2.64	4.71	0.48	2.92	3.28	1.25	4.33	3.43	36.76
1910	2.35	0.82	0.36	3.96	6.20	0.50	1.66	4.04	4.47	1.20	1.44	1.11	28.11
1911	1.13	1.70	1.13	2.33	2.31	4.64	2.06	5.84	7.23	3.64	2.78	1.77	36.46
1912	*0.49	0.80	1.14	2.63	5.33	1.52	4.33	2.74	2.55	4.58	1.70	*0.87	28.68
1913	*1.53	2.80	3.43	2.16	7.01	1.05	3.58	4.37	1.68	3.85	1.74	0.46	33.66
1914	2.64	0.85	1.61	0.98	5.53	6.64	1.23	3.67	2.84	2.96	0.88	2.68	32.51
1915	2.39	2.47	0.50	0.62	8.62	3.05	9.60	5.35	4.35	1.14	2.05	1.30	41.44
1916	4.80	0.85	2.45	1.83	3.74	7.19	0.42	1.16	4.15	4.42	2.36	2.58	35.95

*Values are for Elgin, in the same county.

CHICAGO, COOK COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1871	4.18	1.45	2.66	3.70	3.90	5.56	2.52	2.01	0.74	1.83	3.62	3.44	35.61
1872	0.68	0.84	3.79	3.03	3.24	3.45	3.09	2.59	6.43	0.65	1.06	0.22	29.07
1873	2.56	0.47	0.89	6.22	7.20	1.44	4.04	1.58	3.53	2.43	1.61	4.44	36.41
1874	3.47	1.51	2.15	2.67	2.08	3.25	0.58	3.15	3.76	2.55	2.83	0.63	28.63
1875	0.96	1.99	1.43	2.32	3.64	5.17	7.18	3.29	4.39	4.32	0.75	2.62	38.06
1876	3.22	3.90	4.04	2.07	1.85	5.96	3.11	3.66	3.74	1.20	3.25	0.48	36.48
1877	1.91	0.06	5.37	2.42	1.81	6.04	2.98	3.06	2.02	6.51	6.08	2.75	41.01
1878	1.31	2.12	4.39	5.57	5.22	3.02	6.09	3.66	1.99	5.17	0.83	2.58	41.95
1879	0.54	1.47	2.37	1.98	3.89	3.18	5.58	0.45	1.18	2.72	4.93	2.47	30.71
1880	3.53	2.91	2.25	5.20	4.97	3.50	3.07	4.47	2.25	3.19	0.87	1.11	37.32
1881	0.87	5.98	2.99	1.84	1.85	5.93	4.31	0.54	4.34	6.89	5.97	2.67	44.18
1882	1.55	2.24	3.43	6.72	5.52	5.71	3.43	4.96	0.91	3.40	1.48	1.99	41.34
1883	1.74	4.74	0.42	3.72	7.32	5.61	5.53	1.21	1.36	7.36	5.26	1.59	45.86
1884	1.39	3.27	5.16	3.05	1.53	2.11	3.71	2.50	2.29	3.59	1.80	4.21	34.61
1885	3.18	2.01	0.57	4.00	3.17	5.20	2.44	11.28	2.97	3.87	2.33	3.85	44.87
1886	3.56	1.51	1.79	1.29	1.00	0.94	1.58	3.33	6.93	1.42	1.66	1.76	26.77
1887	3.13	5.10	0.89	0.46	1.38	1.63	1.05	3.35	4.03	2.03	2.41	3.67	29.13
1888	1.56	1.51	2.99	2.13	6.22	1.66	3.93	2.10	0.98	2.95	2.89	1.94	30.86
1889	1.64	1.31	1.43	2.35	5.38	2.93	9.56	0.39	2.75	1.82	3.49	1.90	34.95
1890	2.98	2.42	2.10	3.23	5.13	3.25	2.57	2.58	1.39	4.20	1.59	1.25	32.69
1891	1.99	1.95	2.13	3.14	2.09	2.42	2.47	4.52	0.32	0.36	3.83	1.32	26.54
1892	1.99	1.57	2.21	2.17	6.77	10.58	2.23	1.85	1.34	1.54	2.68	1.63	36.56
1893	2.08	2.44	1.69	4.16	4.93	3.59	3.08	0.18	1.98	1.75	2.45	2.14	30.47
1894	1.55	2.13	2.66	2.65	3.35	1.96	0.60	0.60	8.28	0.84	1.18	1.66	27.46
1895	2.15	1.60	1.32	0.86	1.99	1.79	2.42	6.49	0.89	0.51	5.60	6.76	32.38
1896	1.12	3.48	1.26	2.79	4.16	2.82	3.61	3.52	6.70	1.36	2.16	0.16	33.14
1897	4.53	2.22	3.56	2.23	0.84	3.60	1.47	1.70	0.84	0.18	3.06	1.62	25.85
1898	3.54	2.59	4.60	0.76	2.23	5.30	1.94	3.03	3.16	3.26	2.25	1.11	33.77
1899	0.58	1.60	2.11	0.14	4.35	2.71	6.66	0.91	2.39	2.09	1.14	1.81	26.49
1900	1.21	3.52	1.58	1.02	3.59	2.06	4.64	4.24	1.56	1.35	3.30	0.58	28.65
1901	1.15	2.05	3.38	0.33	2.18	2.42	4.25	2.00	2.92	1.29	0.85	1.70	24.52
1902	0.66	1.53	4.16	2.26	5.08	6.45	5.78	1.44	4.83	1.45	2.03	1.90	37.57
1903	1.09	3.03	1.67	3.77	0.93	1.62	4.78	3.49	4.00	1.09	0.34	2.28	28.09
1904	2.25	1.71	4.57	3.01	1.54	0.55	2.76	4.00	2.65	1.58	0.31	1.21	26.14
1905	1.33	1.95	2.43	3.03	5.14	3.27	5.02	4.46	4.18	1.82	2.05	0.68	35.36

CHICAGO, COOK COUNTY—*Concluded*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1906	1.67	2.37	1.61	1.86	2.09	1.87	4.84	1.43	5.54	2.05	3.08	2.46	30.87
1907	4.21	1.00	2.94	2.37	3.50	3.64	3.15	4.22	4.49	0.93	1.92	2.78	35.10
1908	2.05	3.72	3.48	2.81	6.74	1.48	1.45	6.35	2.09	0.81	2.67	1.18	34.83
1909	1.96	3.82	1.63	7.73	2.18	5.09	1.77	6.20	3.60	1.20	3.84	4.18	43.20
1910	3.07	0.89	0.29	3.84	4.67	0.91	1.79	3.08	3.90	1.79	1.31	1.32	26.86
1911	1.17	2.27	1.45	3.03	3.37	2.54	2.65	3.72	4.08	3.79	3.27	2.54	33.88
1912	0.84	1.57	2.20	2.55	3.97	1.78	3.86	3.59	3.26	3.52	1.45	1.08	29.67
1913	1.33	1.97	3.44	1.91	4.33	1.08	3.30	4.06	1.49	2.28	1.47	0.45	27.11
1914	3.01	0.93	1.87	1.07	5.22	3.53	2.11	3.76	1.56	2.89	0.33	2.33	28.61
1915	1.99	1.92	0.60	1.02	7.04	3.60	5.57	4.33	3.58	0.40	2.08	1.31	33.44
1916	4.84	0.87	2.48	1.60	2.93	7.25	2.22	1.05	2.24	3.88	2.11	2.58	34.05

DAVENPORT, SCOTT COUNTY, IOWA

1871	....	....	....	....	....	3.68	2.30	4.85	0.30	3.19	3.33	1.61	.....
1872	0.13	0.10	1.82	5.06	4.46	3.78	3.80	8.91	5.30	0.61	1.86	0.61	36.44
1873	3.56	0.77	1.43	3.96	6.37	2.16	2.37	0.51	1.00	1.48	0.63	3.84	28.08
1874	4.34	0.74	1.34	2.64	3.45	5.37	3.10	3.68	7.86	1.30	2.47	0.50	36.79
1875	0.38	1.09	0.88	2.30	2.01	4.91	9.36	1.73	4.05	1.63	0.57	3.08	31.99
1876	3.47	3.63	4.35	5.39	6.70	4.25	4.82	4.27	5.50	1.54	2.54	0.36	46.82
1877	1.41	0.07	3.91	3.28	2.82	5.80	3.42	3.21	1.45	4.88	2.53	2.32	35.10
1878	0.36	1.09	2.21	2.89	5.14	4.36	2.19	5.07	1.82	4.21	0.90	0.97	31.21
1879	0.79	1.09	1.80	1.54	5.83	4.57	5.87	4.83	1.43	0.92	4.70	1.02	33.89
1880	3.13	1.72	2.68	4.50	5.09	7.21	4.31	5.90	4.87	0.94	1.28	1.15	42.78
1881	1.34	4.14	3.33	1.11	1.34	7.94	0.91	0.83	5.59	6.85	2.19	1.71	37.28
1882	0.90	0.62	2.90	3.15	5.49	8.43	4.41	2.29	1.39	3.75	1.49	1.78	36.60
1883	1.16	4.42	0.73	3.33	5.46	4.38	3.66	1.02	0.73	5.13	3.58	0.99	34.59
1884	0.75	0.98	3.27	0.77	3.79	3.07	4.51	3.84	4.79	7.17	1.49	3.68	38.11
1885	2.10	1.20	0.17	2.47	1.94	2.08	1.66	12.68	4.19	2.71	1.20	1.95	34.35
1886	2.22	1.52	3.08	1.84	3.73	0.49	0.43	2.67	2.43	3.47	0.74	0.53	23.15
1887	1.43	4.87	0.77	1.17	1.76	1.66	3.09	3.28	5.45	3.41	1.13	3.26	31.28
1888	1.54	1.17	2.70	1.57	9.23	3.86	7.31	2.79	1.38	2.81	3.54	2.59	40.49
1889	0.95	1.44	1.74	3.89	6.34	5.59	8.25	1.11	3.27	1.26	2.17	1.60	37.61
1890	2:49	1.10	2.34	0.36	4.83	4.51	0.85	1.66	2.34	3.63	1.37	0.62	26.10
1891	2.38	0.89	1.68	3.30	2.74	3.56	3.29	5.54	1.50	1.37	3.56	1.64	31.45
1892	1.60	1.38	3.06	5.41	8.84	10.79	4.16	1.53	2.09	0.55	2.01	2.73	44.15
1893	1.14	1.69	2.25	4.50	2.67	3.82	1.75	1.12	3.36	0.80	2.56	1.67	27.33
1894	1.33	1.48	1.88	1.37	1.93	2.16	0.44	2.02	3.02	1.02	1.26	0.61	18.52
1895	1.27	0.38	1.57	0.32	2.28	1.22	5.16	4.79	4.30	0.81	2.50	2.54	27.14
1896	0.89	1.45	0.84	3.41	4.03	2.28	5.68	3.12	3.98	1.67	0.68	0.65	28.68
1897	3.58	1.57	2.82	3.69	1.91	1.37	3.21	0.68	1.52	0.35	1.68	1.53	23.91
1898	3.68	1.86	4.85	3.01	6.73	3.53	1.85	4.96	3.14	3.38	1.37	0.59	38.95
1899	0.31	1.91	1.94	2.94	7.35	4.02	2.84	4.47	0.82	1.46	0.90	2.68	31.64
1900	1.27	2.45	2.92	2.10	4.68	1.01	3.49	4.90	3.66	2.00	1.48	0.21	30.17
1901	1.10	1.59	2.57	0.88	1.37	3.02	1.48	0.46	2.29	0.45	0.79	1.33	17.33
1902	0.60	0.96	1.76	1.40	4.57	7.55	6.88	7.25	3.20	2.81	1.95	1.88	40.81
1903	0.79	1.67	2.06	3.42	5.52	2.28	4.47	4.68	7.09	2.27	0.70	0.78	35.73
1904	2.20	0.72	2.70	2.05	2.64	1.44	3.34	3.60	3.98	1.15	0.18	2.21	26.21
1905	0.63	1.99	2.21	3.45	3.12	7.68	0.99	1.93	3.48	2.73	2.01	1.32	31.54
1906	2.14	2.21	2.20	1.92	2.60	2.69	2.26	3.50	2.47	1.67	2.66	1.61	27.93
1907	3.55	0.22	1.79	1.90	4.33	2.07	7.13	6.48	3.55	0.70	1.08	0.49	33.29
1908	0.69	2.37	2.24	2.22	5.13	4.57	3.30	6.23	1.12	0.87	2.46	0.40	31.60
1909	1.72	2.30	1.60	6.02	3.23	2.80	4.68	2.34	1.50	2.37	3.92	3.12	35.60
1910	1.69	0.59	0.39	3.69	3.42	0.91	2.86	4.31	2.40	0.61	0.22	0.85	21.94
1911	1.41	4.10	1.08	3.63	2.25	2.00	5.12	4.92	5.13	1.57	3.84	1.52	36.57
1912	0.18	1.21	2.34	2.76	2.75	3.19	2.79	2.77	2.28	4.04	0.98	0.56	25.85
1913	1.04	1.57	1.99	2.19	4.89	6.09	0.18	2.06	1.80	3.01	1.26	0.54	26.62
1914	0.87	0.76	2.96	0.89	1.40	3.84	0.44	2.01	6.27	2.15	0.24	1.67	23.50
1915	2.11	2.42	0.83	0.62	6.07	3.47	8.05	1.77	5.75	0.36	4.07	1.13	36.65
1916	4.63	0.37	2.47	2.45	3.52	3.19	0.46	1.25	2.82	3.52	1.45	1.44	27.57

DIXON, LEE COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1886	4.29	2.79	3.68	3.60	6.32	....	0.32	1.38	2.94	....	1.41	1.32	.....
1887	4.21	4.89	1.66	1.10	2.51	2.08	2.35	3.92	3.62	3.76	1.46	9.02	40.58
1888	2.55	1.40	1.89	1.77	7.08	....	....	....	....	....	...	...	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1892	2.22	1.69	2.24	3.27	8.93	7.61	3.84	1.94	2.56	1.07	1.67	2.52	39.56
1893	2.07	1.94	2.83	4.02	2.99	4.42	3.74	0.39	3.22	1.05	2.13	1.69	30.49
1894	2.15	1.97	3.12	2.04	4.28	1.91	0.15	0.92	3.20	0.99	1.42	0.53	22.68
1895	1.22	0.43	0.83	1.17	4.46	1.62	4.59	2.83	1.81	0.82	2.50	2.00	24.28
1896	0.65	0.74	0.81	3.62	5.87	3.18	4.81	3.75	4.66	0.89	1.70	0.44	31.12
1897	3.00	1.25	4.25	3.43	0.96	5.27	1.97	0.56	2.00	0.48	1.90	1.17	26.24
1898	3.27	2.26	4.74	3.29	4.00	2.49	1.55	6.39	3.01	2.56	1.19	0.78	35.53
1899	0.30	1.25	1.67	1.56	6.76	1.91	2.82	1.83	1.48	3.48	0.56	1.81	25.43
1900	2.06	1.86	2.86	1.32	5.25	1.32	4.36	6.18	4.39	3.41	2.10	0.84	35.45
1901	1.09	0.54	2.98	0.84	2.28	2.48	8.98	0.53	2.36	0.90	1.00	1.18	24.61
1902	0.43	1.05	1.81	1.69	8.00	9.75	8.47	2.62	4.63	3.90	2.37	2.13	46.85
1903	2.76	0.90	3.07	4.20	4.35	1.46	4.91	5.64	6.13	3.21	0.73	1.16	38.52
1904	2.23	0.79	3.07	2.29	3.26	2.27	7.58	3.45	5.46	0.86	0.03	2.17	33.46
1905	0.32	1.24	3.85	3.66	6.15	3.85	1.97	4.15	1.23	3.15	1.83	1.12	31.52
1906	2.07	2.46	2.70	2.70	7.24	6.33	5.12	2.09	4.70	1.84	2.19	1.52	40.96
1907	3.43	0.22	2.08	2.11	4.89	3.19	8.76	5.33	4.95	1.71	1.23	0.59	38.49
1908	0.72	2.82	3.38	3.29	5.16	2.24	4.18	5.68	0.84	0.90	2.45	0.84	32.50
1909	2.78	1.89	1.46	6.40	4.34	5.72	1.51	1.13	2.81	2.42	2.59	3.14	36.19
1910	†1.60	0.65	0.20	3.43	4.22	0.45	0.70	3.14	4.76	0.54	0.85	0.89	21.43
1911	0.73	3.52	0.67	3.73	2.69	3.64	3.38	6.62	6.77	2.08	5.47	1.47	40.77
1912	0.50	1.46	1.72	3.07	2.84	1.68	3.34	5.06	3.57	5.18	1.38	1.84	31.04
1913	0.94	1.71	2.64	2.55	5.27	3.15	1.47	2.57	2.57	3.22	0.76	1.17	28.02
1914	1.07	0.93	3.35	1.42	4.78	5.97	2.60	1.15	6.75	3.02	0.42	1.89	33.35
1915	1.11	2.30	1.42	0.35	6.58	4.68	10.34	2.28	5.52	0.30	2.52	1.25	38.65
1916	3.89	0.51	2.30	1.28	3.13	6.37	0.20	4.42	3.04	4.68	1.48	1.78	32.98

Values prior to 1892 are from Prairieville, 7 miles distant.
†Estimated.

DWIGHT, LIVINGSTON COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1896	1.30	1.94	0.89	1.93	3.88	3.13	4.61	2.61	5.09	0.64	3.54	0.11	29.67
1897	5.34	1.46	3.57	2.74	1.81	5.25	2.50	1.60	0.81	0.44	4.77	1.59	31.88
1898	3.80	2.07	6.64	2.95	6.12	3.79	0.29	3.35	4.86	4.42	2.50	1.26	42.05
1899	0.80	2.13	1.76	0.70	2.08	5.07	4.73	2.29	2.57	2.31	2.08	2.06	28.58
1900	1.76	4.50	2.87	1.09	3.72	2.99	4.49	5.03	1.99	1.69	3.35	0.42	33.90
1901	1.60	1.03	3.17	0.50	1.93	3.71	2.00	1.67	2.05	1.44	1.14	2.54	22.78
1902	0.44	1.43	3.82	2.10	5.72	11.53	7.52	3.62	5.36	2.09	3.11	1.49	48.23
1903	1.55	3.17	2.50	5.14	3.24	2.87	....	....	....	....	....	....	.....
1904	....	....	....	....	....	....	....	....	....	....	....	....	.....
1905	....	....	....	....	....	....	....	....	....	....	...	....	.....
1906	2.99	1.76	2.15	2.06	2.07	2.49	4.84	1.85	3.80	1.54	2.80	2.64	30.99
1907	5.38	0.14	2.22	2.56	3.13	2.88	8.85	7.30	6.34	0.45	2.02	3.01	44.28
1908	1.06	3.41	3.27	3.89	6.79	0.97	2.61	1.09	1.22	0.61	2.03	1.14	28.09
1909	1.73	4.29	1.79	7.13	2.48	6.06	1.50	3.58	2.34	2.38	4.24	2.96	40.48
1910	2.37	1.05	0.52	3.84	5.11	3.00	1.36	4.66	5.73	1.44	0.26	1.24	30.58
1911	1.91	1.84	2.10	4.58	2.79	1.78	1.18	2.08	6.67	4.30	2.57	2.27	34.07
1912	0.47	1.10	1.72	4.68	4.12	2.84	2.38	2.96	2.65	3.17	2.16	0.83	29.08
1913	2.59	1.89	4.18	2.77	5.97	2.40	1.61	2.33	0.38	2.98	2.06	1.80	30.96
1914	2.17	0.47	1.29	2.09	3.80	1.80	1.33	2.47	2.69	1.48	0.27	2.00	21.86
1915	1.84	2.00	0.70	1.66	5.09	1.51	9.20	6.81	4.37	0.87	1.65	1.36	37.06
1916	6.26	0.32	2.34	1.34	5.06	6.22	T	1.88	1.86	3.19	1.99	2.23	32.69

GALVA, HENRY COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1864	....	....	....	....	....	....	....	....	2.31	1.94	2.37	2.98	.....
1865	3.00	2.95	2.31	4.44	2.56	2.37	4.31	5.25	7.50	2.25	0.19	0.40	38.08
1866	3.06	1.05	1.93	2.06	1.68	2.69	4.56	3.62	3.25	2.00	0.35	3.22	34.42
1867	0.75	1.75	1.95	2.27	6.41	1.62	1.77	2.82	0.82	0.87	1.99	1.25	24.27
1868	3.99	0.83	5.73	3.15	7.04	2.10	1.25	3.38	2.61	0.20	3.20	1.35	34.88
1869	1.17	2.86	1.64	2.07	5.86	2.43	3.73	7.01	....	0.35	....	....	.....
1870	....	....	....	....	....	0.38	0.66	3.15	....	....	....	....	.....
1871	....	....	....	....	....	....	....	....	....	....	....	....	.....
1872	....	....	....	....	....	....	3.13	5.60	5.08	0.70	1.15	2.20	.....
1873	2.15	0.25	0.48	5.53	5.11	1.60	3.12	1.15	2.18	1.76	1.08	....	.....
1874	2.60	1.16	1.71	4.02	2.18	3.40	1.42	2.53	3.96	1.40	1.93	0.64	26.95
1875	0.14	0.46	1.08	2.62	4.22	4.72	6.66	0.70	2.16	1.24	0.63	1.96	26.59
1876	1.69	2.14	3.56	2.62	5.28	4.67	4.26	0.58	5.10	2.05	1.91	0.58	34.44
1877	....	....	2.18	3.15	2.71	3.87	3.36	1.89	1.05	4.93	3.20	2.56	.....
1878	0.24	1.08	2.40	4.87	4.43	3.18	2.16	6.34	1.02	3.20	0.60	2.20	31.67
1879	0.81	0.75	1.31	2.16	0.87	3.66	3.49	3.17	2.06	2.54	2.81	1.11	24.74
1880	3.28	2.30	3.18	3.54	5.23	3.26	2.31	2.52	1.74	1.73	1.83	1.24	32.16
1881	0.92	3.89	3.41	1.53	1.84	3.36	3.94	0.62	4.16	5.93	2.77	1.68	39.00
1882	1.51	1.06	2.93	?.93	4.96	6.23	3.94	6.56	0.92	3.19	1.56	1.71	37.50
1883	1.87	2.75	0.51	4.14	4.31	3.54	4.19	....	....	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1893	0.95	1.65	2.88	5.73	2.45	1.37	1.08	0.69	3.57	0.46	2.25	1.54	24.62
1894	1.64	0.88	2.53	1.71	2.18	4.14	0.99	1.78	5.17	1.16	1.62	0.62	24.42
1895	1.38	0.19	0.35	1.08	2.53	1.57	5.58	2.74	5.17	0.87	2.18	4.20	27.74
1896	1.17	0.80	0.79	4.24	5.25	3.10	9.45	3.69	6.68	1.30	1.42	0.80	38.19
1897	4.91	1.23	4.64	2.61	1.06	0.92	3.60	1.01	2.46	0.23	2.00	1.08	25.75
1898	3.88	1.43	5.43	2.77	8.74	9.86	0.96	7.13	3.84	2.73	2.19	0.61	49.07
1899	0.24	1.39	2.70	1.44	6.07	2.57	2.82	2.40	2.46	4.34	1.28	1.71	29.37
1900	1.71	2.49	2.95	1.35	4.28	0.51	3.69	3.21	4.65	2.61	1.68	0.16	34.24
1901	1.18	1.77	2.70	0.95	1.51	3.70	4.59	1.38	2.84	1.17	1.08	1.09	23.91
1902	0.44	1.29	4.17	2.07	5.01	8.96	10.54	3.78	6.04	3.28	1.82	1.64	49.04
1903	0.74	1.95	2.72	4.07	5.42	3.64	5.77	4.91	5.30	1.88	1.08	0.92	38.40
1904	2.18	0.89	3.66	2.60	3.05	2.49	8.83	5.97	5.49	0.24	0.23	1.96	37.59
1905	0.67	1.64	2.34	4.78	3.96	5.16	2.16	2.58	1.47	2.85	1.87	1.56	31.04
1906	3.01	2.19	2.24	1.92	2.33	3.49	2.10	2.50	4.02	0.69	2.09	1.78	28.36
1907	3.24	0.20	1.27	3.16	2.83	2.44	5.23	6.41	2.69	0.65	1.43	1.11	30.66
1908	1.83	3.01	4.65	3.50	9.82	3.84	2.68	3.91	1.57	1.42	3.64	0.48	39.85
1909	1.17	3.65	1.53	4.08	3.32	2.98	4.74	0.90	2.85	2.60	5.39	3.64	36.90
1910	1.75	1.26	0.33	2.52	5.55	1.53	2.24	0.80	4.11	1.17	0.32	0.89	22.47
1911	1.71	2.75	1.27	3.57	1.62	2.81	3.99	2.44	3.29	2.05	2.76	2.89	35.65
1912	3.18	1.34	2.28	4.65	3.56	2.56	3.16	1.72	2.92	5.85	2.17	0.78	34.12
1913	1.31	2.08	4.35	2.36	4.64	6.18	0.66	3.75	1.85	2.05	1.74	0.69	31.61
1914	0.98	0.83	2.12	1.58	2.37	3.45	0.28	2.03	6.41	2.83	0.38	1.69	24.40
1915	1.81	2.22	0.83	0.80	7.16	3.25	6.85	2.40	4.96	0.28	3.92	0.66	35.14
1916	4.76	0.36	2.99	2.18	5.30	4.71	1.09	2.87	3.85	4.05	1.61	1.98	35.75

Values from 1864 to 1883, inclusive, are for Elmira, 12 miles distant.

HENRY, MARSHALL COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1871	2.59	2.49	3.20	1.60	1.80	4.70	1.80	3.70	0.50	2.20	2.90	1.90	29.38
1872	....	0.40	0.55	4.10	3.50	5.30	3.30	6.30	5.80	1.50	1.20	0.70	.....
1873	2.52	0.80	0.90	4.50	4.50	0.90	2.20	2.00	2.50	1.80	1.40	4.65	28.67
1874	3.40	1.58	1.20	2.50	3.20	3.30	1.50	1.40	3.20	1.90	3.20	0.50	26.88
1875	0.40	1.90	1.35	2.30	3.70	3.50	8.30	2.10	5.10	1.90	0.67	2.70	33.92
1876	3.40	2.60	2.90	4.00	3.40	5.60	6.10	1.20	2.50	1.20	3.60	0.76	37.26
1877	0.60	....	2.60	3.70	2.40	5.90	3.10	1.00	0.90	6.10	4.00	2.90	.....
1878	0.50	1.80	2.30	5.40	6.10	3.10	1.10	5.60	0.90	2.90	0.40	1.80	31.90
1879	0.60	....	....	....	....	....	....	....	....	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1887	2.24	4.55	0.72	0.73	1.52	1.70	1.30	4.80	2.70	2.96	1.48	3.58	28.28
1888	1.07	1.57	2.54	0.93	6.87	2.29	2.14	1.25	1.21	2.71	3.10	2.22	27.90
1889	1.65	0.85	1.60	2.60	4.12	5.72	4.97	0.75	3.83	2.02	1.86	1.45	31.42
1890	2.05	2.03	2.55	3.39	4.54	3.98	0.66	1.45	3.07	5.57	1.45	0.20	30.94
1891	2.36	1.35	3.13	3.50	2.68	6.79	1.99	4.45	0.98	1.43	4.66	2.28	35.60
1892	1.20	0.60	2 63	3.33	12.57	10.01	4.22	0.32	1.25	0.70	2.65	2.30	41.78
1893	1.70	0.90	....	5.10	1.60	2.95	1.25	0.38	1.91	0.95	....	....	.....
1894	....	....	....	....	3.20	4.91	0.25	1.82	7.06	1.29	....	1.11	.....
1895	1.00	0.20	0.86	1.56	1.53	1 39	9.66	2.42	1.46	1.24	4.31	5.16	30.79
1896	0.92	0.97	0.93	4.45	7.05	2.81	9.65	2.13	6.95	0.08	2.75	0.12	38.81
1897	5.47	1.65	3.79	2.36	0.95	7.35	2.92	0.71	0.95	0.18	4.33	1.03	31.69
1898	4.00	†2.10	†6.15	3.68	6.41	3.61	1.10	7.10	6.91	3.11	2.46	1.32	47.95
1899	0.33	1.94	2.26	1.06	5.64	3.00	4.57	1.63	3.12	3.45	1.97	2.48	31.45
1900	1.82	3.67	3.15	1.68	4.76	2.52	2.76	6.79	3.64	3.94	2.25	0.14	37.12
1901	1.45	1.23	3.97	0.96	2.20	2.83	3.40	1.90	2.56	0.83	1.50	1.76	24.59
1902	0.46	1.60	3.60	2.63	4.14	11.21	11.01	5.44	6.10	1.60	3.38	1.88	53.05
1903	1.20	2.59	3.84	5.22	3.85	2.67	3.28	5.50	6.68	1.35	1.69	1.86	39.73
1904	2.84	1.43	4.28	3.51	3.85	3.22	5.73	4.51	3.66	0.31	T	1.71	35.05
1905	1.09	1.76	2.64	3.87	3.60	5.46	2.51	4.20	1.86	2.91	2.21	1.63	33.74
1906	2.23	1.70	2.31	1.65	2.53	3.31	2.57	3.91	5.03	1.92	2.56	2.17	31.89
1907	5.85	0.16	3.20	2.79	3.65	3.79	5.43	4.58	4.51	0.80	1.92	1.23	37.91
1908	1.12	2.51	3.00	4.64	8.90	4.60	2.82	0.94	0.80	0.77	1.87	0.81	32.78
1909	1.44	3.55	1.70	7.11	3.41	3.77	3.81	3.93	3.93	2.48	4.66	3.20	42.99
1910	2.24	1.11	0.12	3.28	6.00	0.96	1.27	1.77	3.53	1.48	0.54	1.25	23.55
1911	2.10	1.91	1.79	*3.57	*1.62	*2.81	3.25	2.99	7.19	2.24	2.61	2.29	34.37
1912	0.18	1.16	1.78	4.87	5.15	1.78	2.30	2.24	3.01	5.12	2.21	1.19	30.99
1913	1.69	3.25	3.91	2.20	4.15	3.74	0.51	*3.75	2.21	2.65	2.09	1.29	31.44
1914	1.53	0.89	4.41	1.33	3.25	2.26	0.22	1.89	4.07	2.99	0.21	1.67	24.72
1915	2.07	2.27	0.95	....	5.51	2.49	6.27	2.17	5.14	1.27	2.82	0.76	.....
1916	5.80	0.56	2.82	1.07	....	6.58	2.29	0.68	2.90	4.04	1.87	1.60	.....

Values from 1871 to 1893, inclusive, are for Hennepin, 10 miles distant.

Values from May, 1894, to January, 1898, inclusive, are for Clear Creek, less than 17 miles distant.

†Estimated. *Values are for Galva.

JOLIET, WILL COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1887	....	....	....	....	0.97	2.07	2.47	2.72	2.96	2.95	1.85	3.17	.....
1888	0.90	1.00	2.35	2.10	3.50	1.70	0.70	6.00	0.90	3.30	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1893	....	....	....	....	....	....	....	....	....	....	1.87	1.57	.....
1894	1.16	1.31	2.87	2.23	3.69	2.84	0.46	0.85	5.99	1.18	1.68	1.00	25.26
1895	1.82	0.67	1.04	1.92	1.95	1.26	4.32	2.96	0.93	0.67	2.90	6.62	27.06
1896	1.14	2.07	1.15	2.82	5.28	3.89	4.97	2.75	6.69	0.86	2.96	0.36	34.94
1897	6.67	1.84	3.80	2.87	1.25	5.19	1.59	0.55	0.63	0.44	4.42	1.68	30.93
1898	4.05	2.28	6.12	1.42	3.82	7.89	1.59	4.69	3.20	4.53	2.61	2.15	44.35
1899	0.82	1.68	2.23	0.35	4.69	2.17	5.26	1.74	2.44	2.39	1.15	1.70	26.62
1900	1.58	4.29	2.24	0.79	4.27	1.80	5.08	5.74	2.05	1.61	3.10	0.53	33.08

JOLIET, WILL COUNTY—*Concluded*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1901	1.88	1.62	3.62	0.56	0.81	3.14	5.42	2.84	2.55	0.85	1.63	2.36	27.28
1902	0.55	1.48	5.51	2.36	7.48	12.86	9.38	3.15	6.28	2.44	2.99	1.63	56.11
1903	1.05	2.92	2.22	3.62	2.49	1.68	4.46	4.77	4.98	1.40	0.86	2.18	32.63
1904	2.42	1.75	4.97	3.81	3.19	0.94	2.97	3.19	4.95	1.44	0.10	1.63	31.36
1905	1.18	1.43	2.29	4.13	5.42	5.10	4.18	4.29	3.63	3.57	2.66	1.46	39.34
1906	2.23	2.30	1.61	1.67	2.00	1.85	2.51	4.00	5.63	2.76	2.63	3.18	32.37
1907	5.70	0.32	3.00	2.28	3.32	1.70	5.38	4.66	6.13	0.66	1.86	3.07	38.08
1908	0.77	2.66	4.33	3.32	6.95	1.30	3.79	3.80	1.32	0.82	2.77	1.30	33.13
1909	1.12	3.38	1.56	6.60	3.46	3.80	1.69	2.95	3.09	1.68	4.55	3.50	37.38
1910	2.52	1.21	0.24	3.81	4.90	0.81	1.46	3.17	2.75	1.68	0.62	1.12	24.29
1911	1.58	1.62	1.39	4.45	3.65	4.65	2.46	4.54	12.27	4.18	2.87	1.91	45.57
1912	0.22	1.09	1.41	2.77	3.62	2.46	1.55	1.70	2.34	4.26	1.67	1.01	24.10
1913	1.59	1.46	3.48	2.51	5.21	1.74	3.48	3.41	1.37	2.93	1.13	0.36	28.67
1914	1.96	0.63	1.45	1.55	5.95	3.57	1.26	4.60	1.89	1.54	0.26	1.72	26.38
1915	1.54	1.71	0.33	1.03	4.18	3.16	6.90	4.30	3.18	0.58	1.56	0.99	29.46
1916	5.43	0.55	1.70	1.15	3.84	5.76	0.90	1.22	3.25	5.18	2.08	2.32	33.38

From November, 1893, to April, 1895, inclusive, the values are for Braidwood, 19 miles distant.

KNOXVILLE, KNOX COUNTY, ILLINOIS

1861	....	2.76	3.22	3.60	2.65	3.71	3.56	1.52	6.00	4.35	0.98	1.70	.....
1862	3.47	0.44	2.38	4.78	3.27	5.71	5.58	5.67	5.58	0.96	2.03	2.88	42.75
1863	2.85	2.66	1.80	....	3.62	....	0.74	1.80	1.85	4.74	0.84	2.41	.....
1864	1.28	0.57	3.14	4.02	1.80	4.08	3.40	2.22	2.16	2.60	2.96	4.55	32.78
1865	0.30	2.69	3.52	4.65	1.58	3.94	6.74	4.70	5.08	2.39	0.00	0.70	36.29
1866	2.75	0.98	1.87	2.52	1.14	0.88	4.64	4.82	8.38	2.00	0.41	1.58	31.97
1867	0.45	2.36	1.92	1.16	6.33	8.18	0.41	3.21	0.94	0.91	1.40	0.96	28.23
1868	0.80	0.50	5.40	5.74	6.74	1.22	1.79	3.51	5.28	....	3.74	1.00	.....
1869	1.62	2.30	1.30	1.01	3.18	8.54	9.00	6.31	1.06	1.54	2.80	1.22	39.88
1870	0.63	0.30	3.86	0.60	1.35	1.27	1.10	3.70	3.96	4.46	0.60	1.08	22.91
1871	2.80	1.50	2.05	2.64	2.72	3.41	3.51	6.46	0.90	3.80	1.94	2.60	34.33
1872	....	....	1.70	2.25	2.34	4.80	....	....	....	....	....	....	.....
1873	....	....	....	....	....	....	....	....	....	....	....	....	.....
1874	....	....	....	....	....	....	....	6.65	3.00	1.27	2.76	1.08	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1885	....	....	0.20	3.56	2.57	3.40	3.13	7.40	4.15	3.69	0.91	3.75	.....
1886	3.05	2.00	4.50	2.68	8.15	3.40	1.00	3.37	5.03	3.35	1.51	1.02	39.06
1887	3.20	6.55	1.25	1.55	3.60	3.00	6.60	3.95	....	2.75	2.05	3.60	.....
1888	1.45	2.50	3.75	1.62	7.90	4.10	3.60	5.25	1.65	3.45	4.15	2.85	42.27
1889	1.73	1.30	1.35	4.30	3.90	4.13	2.00	0.50	2.35	1.65	3.20	1.90	28.31
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1895	1.85	0.39	1.45	3.61	3.62	1.40	8.81	2.54	6.10	1.00	3.51	5.13	39.41
1896	1.15	1.40	1.57	3.62	4.19	3.65	7.25	4.91	5.28	2.06	2.30	0.38	37.76
1897	6.32	0.98	5.67	4.18	1.20	2.38	4.45	1.01	2.05	0.20	2.47	1.47	32.38
1898	5.30	1.86	5.90	3.85	7.98	5.02	0.97	10.18	5.69	2.48	2.67	0.83	52.73
1899	0.42	1.74	3.01	1.55	6.87	2.00	2.71	1.14	2.95	2.48	1.42	2.64	28.93
1900	1.95	3.66	3.20	1.22	3.97	0.42	3.21	4.23	3.86	2.94	2.28	0.45	31.39
1901	1.11	1.07	2.55	1.14	1.25	3.17	2.51	0.65	2.40	0.91	1.15	0.89	18.80
1902	0.52	1.42	3.66	2.22	3.70	9.63	3.07	7.90	4.04	3.27	2.00	2.07	43.50
1903	1.10	1.72	2.95	5.62	4.57	2.43	1.53	6.40	2.45	2.20	1.08	0.98	33.03
1904	3.06	0.74	3.58	2.32	3.81	3.50	7.87	3.05	5.54	0.10	0.20	1.77	35.54
1905	1.07	1.13	1.96	5.38	3.38	4.26	4.59	4.37	2.08	2.69	2.30	1.78	34.99
1906	3.30	2.13	3.51	2.52	2.60	2.50	3.03	2.88	4.30	1.46	2.65	1.81	32.69
1907	....	0.07	....	0.29	2.29	....	5.92	5.84	2.08	0.11	1.32	....	.....
1908	0.99	4.39	2.78	2.19	9.55	2.53	4.10	3.81	1.39	1.38	3.24	1.36	37.71
1909	1.59	3.24	1.76	4.47	4.03	2.56	7.41	0.98	3.63	3.52	5.52	4.18	42.89

Values from 1861 to 1874, inclusive, are for Galesburg; those from 1885 to 1889, inclusive, are for Oneida; and those for 1895 to 1908, inclusive, are for Knoxville. Galesburg is 6 miles from Knoxville. Oneida is 12 miles from Knoxville.

LA GRANGE, COOK COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1892	....	0.83	2.20	2.76	8.00	12.25	....	....	1.70	0.81	2.24	1.93	.....
1893	1.91	1.79	2.15	5.61	2.27	5.30	2.96	0.28	2.84	0.52	2.26	2.00	29.84
1894	1.64	1.72	....	....	3.16	2.09	....	....	3.87	1.04	1.45	0.71	.....
1895	1.64	0.45	0.85	1.17	2.24	2.00	....	5.69	1.10	0.77	5.09	6.04	.....
1896	1.16	2.39	1.04	4.21	4.73	2.63	....	....	5.39	0.85	3.08	0.10	.....
1897	6.09	1.83	4.00	3.50	1.85	3.74	2.97	1.57	0.80	0.33	3.82	1.36	31.86
1898	4.30	2.60	5.87	1.14	3.50	6.92	2.77	4.59	3.97	4.21	2.69	1.56	44.12
1899	0.37	1.91	2.06	0.35	6.98	1.86	8.80	2.18	1.78	2.54	1.53	1.68	30.94
1900	1.30	3.38	1.84	0.95	3.78	3.40	5.64	4.81	1.95	1.12	3.32	0.32	31.81
1901	1.45	2.03	3.78	0.47	0.96	4.38	2.87	2.00	3.56	1.65	1.04	1.33	25.52
1902	0.53	1.34	3.19	1.89	6.16	10.64	7.51	2.08	5.91	2.09	2.68	2.31	46.33
1903	0.86	2.90	2.51	3.51	1.27	2.06	....	....	5.54	1.50	0.37	2.08	.....
1904	1.65	1.56	5.30	2.02	1.57	0.79	3.55	3.06	3.69	1.59	T	0.99	25.77
1905	0.72	1.06	1.58	3.41	5.91	3.33	3.56	2.65	4.25	1.65	2.77	0.46	31.35
1906	1.61	2.50	2.56	1.59	3.42	2.49	2.16	5.58	6.19	2.72	2.69	2.36	35.82
1907	5.17	0.40	2.71	2.45	2.61	3.99	4.54	4.28	5.72	1.05	1.15	1.81	35.88
1908	1.41	3.40	3.20	2.71	6.16	1.30	3.54	7.75	1.40	0.89	2.40	1.34	35.50
1909	1.68	3.73	1.42	8.22	2.54	6.33	1.28	6.45	3.26	1.24	4.05	4.12	44.32
1910	2.35	0.83	0.05	3.47	5.13	1.06	†1.62	†3.12	4.39	1.44	1.73	1.28	26.47
1911	1.23	2.88	1.32	3.40	2.44	2.57	2.39	3.45	3.64	3.70	2.90	2.01	31.93
1912	0.40	1.45	2.02	2.91	5.47	2.01	2.71	2.65	3.68	4.09	1.48	1.02	29.89
1913	1.10	2.13	3.39	2.41	5.28	0.89	*3.48	*3.41	*1.37	2.54	1.71	0.28	27.99
1914	1.94	0.53	2.52	1.33	5.95	3.38	†1.19	†4.18	†1.78	2.91	0.49	2.35	28.50
1915	1.89	2.01	0.45	0.55	5.87	4.24	7.32	3.58	....	0.61	1.68	0.94	.....
1916	5.17	0.71	2.29	1.09	3.38	3.12	0.88	1.28	....	4.04	2.30	2.33	.....

†Estimated from surrounding stations.
*Values are for Joliet.

LANARK, CARROLL COUNTY, ILLINOIS

1887	....	....	....	....	1.89	1.89	3.81	3.68	4.76	2.34	1.64	3.68	.....
1888	1.39	1.26	4.04	1.52	6.46	2.72	4.96	2.91	1.24	2.40	3.13	3.02	35.05
1889	1.66	1.17	1.49	3.87	3.55	3.17	6.42	0.38	4.71	1.02	1.10	2.63	31.17
1890	2.76	1.61	2.13	....	3.71	12.82	0.78	2.96	1.36	5.43	1.87	0.81	.....
1891	1.59	1.48	2.86	3.20	3.22	3.18	4.39	2.63	1.84	1.58	3.71	2.06	31.74
1892	2.13	1.83	2.97	6.05	9.29	9.57	....	....	....	....	....	....	.....
1893	....	....	....	....	....	....	....	....	....	....	....	....	.....
1894	....	....	....	....	....	*3.00	*0.33	*3.19	*6.49	*3.68	*1.60	*0.63	.....
1895	*1.82	*0.29	*0.70	*0.18	3.78	1.60	4.28	1.61	1.70	0.86	2.02	1.41	20.25
1896	0.49	1.02	1.21	5.05	7.92	2.92	5.06	3.23	4.78	1.97	0.83	0.95	35.43
1897	2.48	0.89	3.20	2.67	1.24	5.58	1.06	0.59	1.54	0.39	1.79	1.46	22.89
1898	1.85	1.52	2.66	2.76	3.87	2.12	2.00	7.28	3.66	3.45	1.07	0.84	32.53
1899	0.27	0.20	1.31	2.12	7.74	2.72	3.66	1.67	1.33	2.67	1.75	1.73	27.17
1900	1.48	2.35	1.51	2.36	4.23	1.91	6.17	4.46	2.87	2.32	1.88	0.72	32.26
1901	0.90	0.70	2.75	0.66	2.72	1.87	1.15	0.27	2.58	1.39	1.06	1.26	17.31
1902	0.46	1.27	1.44	2.65	7.14	10.51	9.79	2.26	5.63	3.08	4.53	2.78	51.54
1903	1.06	1.90	2.94	4.02	5.05	1.88	9.09	6.26	5.64	2.02	1.06	1.71	42.63
1904	*0.65	*0.60	2.68	3.08	3.37	1.12	2.94	5.03	7.49	1.20	0.17	2.65	30.98
1905	0.57	1.26	3.06	2.41	4.06	3.15	4.01	7.90	2.62	4.29	2.16	0.96	36.45
1906	2.60	1.79	2.44	2.17	4.18	5.24	4.32	6.05	3.70	1.95	3.48	1.71	39.63
1907	2.67	0.22	1.51	2.50	3.23	4.48	3.72	5.13	6.20	1.43	1.41	0.93	33.43
1908	0.62	1.94	3.02	2.91	6.14	5.13	6.67	2.69	0.89	1.16	3.02	0.49	34.68
1909	3.58	1.67	1.14	7.23	2.46	6.40	1.53	1.92	1.81	1.64	4.37	2.57	36.32
1910	1.39	0.40	0.28	3.01	3.31	0.71	1.34	3.26	2.37	0.66	0.71	0.40	17.84
1911	0.46	2.59	0.71	4.48	4.58	3.81	3.42	12.19	6.89	1.45	3.98	1.49	46.05
1912	0.40	0.96	1.13	1.77	3.01	2.47	5.83	6.13	3.62	4.35	1.78	1.58	33.03
1913	0.91	0.68	1.67	1.91	6.94	1.62	2.08	5.56	2.86	3.61	1.32	0.51	29.67
1914	0.87	0.39	3.15	1.55	3.97	5.00	1.47	0.79	8.44	2.53	0.20	1.72	30.08
1915	1.38	2.10	0.57	0.10	7.65	3.70	9.09	3.08	5.30	0.51	3.29	0.41	37.18
1916	3.40	0.49	1.84	....	....	....	....	....	....	....	....	....	.....

*Values are for Zion, in the same county.

LASALLE, LASALLE COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1903	....	1.27	2.94	....	....	....	....	4.95	6.27	1.02	0.65	0.33	.....
1904	1.96	0.82	2.67	2.86	1.99	....	....	....	....	....	0.08	1.65	.....
1905	0.90	1.09	1.88	3.71	5.51	4.48	1.49	3.19	3.15	1.86	1.98	1.28	30.37
1906	2.15	2.01	2.08	1.16	1.85	3.00	2.62	7.25	4.89	1.12	1.98	2.14	32.25
1907	4.46	0.09	2.03	2.86	3.39	3.45	5.94	4.29	4.99	0.87	1.55	1.56	34.98
1908	0.96	2.76	3.07	2.89	6.69	2.68	3.72	1.82	1.09	0.41	1.62	0.83	28.54
1909	1.28	3.06	1.40	5.93	3.05	2.33	2.52	4.00	3.15	1.53	3.82	3.64	35.71
1910	1.93	1.17	0.19	3.78	6.02	0.89	0.79	3.74	5.09	1.08	0.77	1.11	26.51
1911	1.78	2.16	1.81	3.87	1.97	3.32	3.16	6.45	7.42	2.40	2.26	2.04	37.64
1912	0.13	0.73	1.47	2.98	3.78	2.77	2.40	4.35	2.54	4.62	1.54	0.98	28.24
1913	1.29	2.50	3.03	1.53	4.45	3.32	1.42	3.71	1.92	*2.70	1.82	1.42	28.61
1914	1.24	0.78	2.22	0.94	3.35	2.58	1.19	2.88	3.85	2.14	0.24	1.38	22.74
1915	1.22	2.18	0.54	1.09	5.80	1.84	3.13	2.86	7.84	0.98	2.07	0.86	35.41
1916	5.00	0.79	3.09	1.34	4.58	3.03	0.20	2.30	2.82	....	1.55	....	.....

*Interpolated from Ottawa, in the same county.

MARTINTON, IROQUOIS COUNTY, ILLINOIS

1885	....	....	....	....	....	3.10	3.75	2.11	4.45	6.65	1.36	4.02	.....
1886	2.06	1.78	2.04	2.33	5.38	3.40	3.06	3.75	5.23	0.62	1.49	1.42	32.56
1887	1.21	5.08	1.02	2.17	1.95	2.05	2.12	3.37	2.74	1.65	2.90	4.11	30.32
1888	2.82	1.50	2.53	2.11	4.96	4.43	2.49	0.61	0.50	2.86	3.20	1.92	29.43
1889	1.39	1.70	1.65	1.28	6.40	5.65	6.54	2.01	2.71	2.68	3.15	1.58	36.69
1890	4.79	1.77	3.28	3.86	5.37	5.78	1.57	2.70	2.08	3.73	1.56	....	.....
1891	....	....	....	....	....	....	....	....	....	....	....	....	.....
1892	....	....	2.27	7.88	9.47	3.98	1.35	2.42	2.51	0.52	1.95	1.44	.....
1893	1.85	6.70	3.15	6.95	5.42	1.35	....	....	....	....	....	....	.....
1894	....	....	....	....	....	....	....	....	....	....	0.78	1.73	.....
1895	0.87	T	0.53	3.08	1.35	1.29	5.09	1.98	3.46	1.17	2.80	7.91	29.43
1896	1.30	1.94	0.89	....	3.25	4.42	7.02	3.62	5.50	0.25	1.98	0.18	.....
1897	3.61	1.37	3.96	2.26	1.78	4.44	1.67	1.28	0.29	0.61	5.71	2.20	29.18
1898	3.44	1.90	4.38	1.98	5.66	2.65	1.11	4.03	5.77	4.86	2.81	1.80	39.89
1899	1.37	0.89	2.14	0.20	4.02	2.22	2.55	2.19	2.30	3.17	1.84	3.11	26.00
1900	0.74	4.56	3.52	1.31	4.22	2.33	4.34	5.10	2.09	1.82	5.78	0.52	36.83
1901	1.55	1.30	4.06	1.37	2.19	4.76	1.85	3.15	1.82	2.90	1.10	3.10	29.15
1902	0.83	1.81	4.14	3.36	4.51	12.58	6.29	2.37	6.84	1.72	3.37	2.91	50.68
1903	1.29	2.00	1.28	7.18	4.67	3.33	4.34	3.88	2.40	2.54	0.79	0.29	38.99
1904	2.02	1.60	4.08	3.26	3.92	1.68	2.03	3.24	4.81	1.23	0.09	1.85	29.81
1905	0.81	2.05	1.79	3.96	8.93	4.38	2.68	4.91	2.77	2.10	2.68	1.60	38.66
1906	3.26	1.77	3.54	2.03	4.25	3.17	6.02	7.19	4.59	1.80	3.25	3.40	44.27
1907	4.57	0.20	5.23	2.56	2.86	4.04	5.65	6.62	4.17	0.65	2.70	4.68	43.98
1908	1.75	4.05	2.79	4.30	9.95	1.65	1.24	2.86	2.60	0.67	1.58	2.08	35.52
1909	2.30	4.39	2.00	4.90	2.95	4.27	2.45	7.31	3.82	3.35	5.58	4.10	47.37
1910	2.55	1.07	0.45	2.27	4.47	1.25	4.36	5.80	4.50	2.87	0.26	1.16	31.01
1911	1.48	1.06	1.50	4.12	5.79	1.90	0.80	2.65	9.40	2.99	2.00	1.86	35.50
1912	0.62	0.97	2.03	3.87	6.58	4.98	2.31	4.51	1.92	2.70	2.15	0.56	33.20
1913	3.38	0.96	5.22	3.35	5.79	1.87	2.19	3.49	2.22	4.00	2.40	1.22	36.09
1914	1.89	1.01	1.86	2.38	4.72	1.56	1.47	2.62	3.26	0.94	0.33	1.85	28.89
1915	1.95	1.89	0.69	3.10	4.15	1.59	12.52	3.39	4.71	0.92	1.32	1.45	37.68
1916	5.13	0.26	1.08	1.65	7.10	4.91	0.61	1.47	2.07	....	....	....	.....

Values for 1885 to 1893, inclusive, are from Watseka, 9 miles distant.
Values from November, 1894, to March, 1896, inclusive, are for Gilman, 16 miles distant.

MINONK, WOODFORD COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1886	1.70	0.46	2.95	3.20	4.22	3.45	0.60	0.65	4.95	1.60	0.70	1.05	25.53
1887	0.85	4.95	0.75	1.50	2.10	0.25	0.92	2.60	....	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1895	....	....	....	....	....	....	....	....	....	0.87	4.08	6.33	.....
1896	1.26	1.44	1.08	3.64	5.50	3.87	5.33	2.67	4.53	0.20	2.32	T	31.84
1897	5.14	1.45	3.18	2.93	1.05	2.57	2.93	0.92	1.90	0.13	3.92	1.20	27.32
1898	4.21	1.78	5.00	2.87	6.84	2.92	0.58	4.76	5.47	3.86	2.13	1.04	41.46
1899	0.50	1.79	2.24	1.58	4.59	3.75	2.19	1.74	4.20	3.47	0.95	2.31	29.31
1900	1.30	4.45	3.02	1.16	3.09	1.40	2.21	6.43	2.54	2.24	2.66	0.37	30.87
1901	1.49	1.31	3.60	0.61	2.41	2.50	2.40	0.75	1.92	0.75	0.78	1.87	20.39
1902	0.48	1.41	3.89	2.23	2.43	9.41	7.76	8.56	4.59	1.59	3.15	1.79	47.29
1903	0.71	2.16	2.80	4.65	3.23	4.12	6.24	4.49	7.14	2.23	0.92	1.47	40.16
1904	2.51	1.48	3.95	2.75	3.70	1.61	6.23	2.69	4.14	0.17	T	1.43	30.66
1905	1.16	1.06	1.97	3.88	4.54	3.35	2.07	2.59	2.64	2.10	1.68	1.42	28.46
1906	1.89	1.43	1.95	0.92	1.62	2.46	1.66	2.51	4.37	1.50	2.04	1.99	24.34
1907	3.99	0.06	1.72	2.59	4.14	4.19	5.72	3.91	3.82	0.44	1.89	2.46	34.93
1908	0.80	3.83	2.42	4.06	8.77	1.21	1.88	1.62	0.39	0.69	1.60	0.67	27.94
1909	1.62	3.50	1.68	5.62	2.56	3.31	1.98	3.32	1.98	2.43	3.83	2.90	34.73
1910	1.45	1.08	0.03	3.63	4.52	4.07	1.31	2.46	3.91	0.93	0.33	1.16	24.88
1911	2.06	1.80	2.43	3.39	1.32	3.02	2.87	3.49	10.13	3.75	2.11	2.47	38.84
1912	0.54	1.55	2.05	5.57	5.21	4.08	2.85	1.88	2.85	3.61	2.55	0.78	33.47
1913	2.00	2.67	3.45	3.08	5.29	2.00	1.95	2.21	1.32	2.39	2.12	1.44	29.92
1914	1.94	1.08	1.39	1.57	2.94	4.21	0.58	1.52	2.99	2.74	0.05	1.67	22.68
1915	1.40	1.75	0.87	1.20	4.47	1.32	9.12	5.97	5.24	0.69	1.53	0.89	34.45
1916	....	0.28	2.83	1.37	5.22	7.05	0.18	4.50	2.61	4.21	2.75	1.85	.....

MONMOUTH, WARREN COUNTY, ILLINOIS

1887	....	....	1.30	....	....	....	5.20	....	3.48	....	1.30	....	.....
1888	3.01	....	....	....	....	....	....	....	....	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1893	....	2.24	3.48	....	....	....	....	....	....	....	....	1.57	.....
1894	1.78	1.35	2.22	2.10	2.10	2.04	1.02	2.00	5.61	1.16	1.52	1.49	24.39
1895	1.42	0.18	0.84	2.54	2.04	2.97	5.50	3.04	4.26	0.78	2.06	4.81	30.44
1896	1.10	1.35	0.68	4.50	4.76	3.56	5.79	6.68	6.02	1.76	0.81	0.35	37.36
1897	5.14	0.82	2.63	3.25	0.94	2.00	5.26	0.65	2.78	0.13	1.87	1.69	27.16
1898	3.20	1.38	3.65	2.73	6.60	4.67	1.50	9.23	7.15	2.34	1.53	0.47	44.45
1899	0.37	1.49	3.10	2.84	6.61	1.24	1.49	3.27	2.26	2.38	0.65	1.43	27.13
1900	1.67	2.92	2.10	1.01	2.93	0.82	2.65	4.23	5.31	2.86	2.39	0.25	29.14
1901	1.24	1.19	2.00	1.23	1.28	4.96	5.44	0.37	3.00	1.03	0.87	0.78	23.39
1902	0.30	0.99	3.03	3.13	3.65	13.97	7.51	8.80	3.48	3.39	2.28	2.56	53.09
1903	0.63	1.66	2.11	6.58	3.63	2.27	1.92	6.32	6.57	2.35	0.72	0.66	35.42
1904	2.85	0.80	3.62	2.51	4.61	2.86	8.66	5.63	4.29	0.36	0.22	1.67	38.08
1905	0.83	2.04	1.77	4.98	3.64	3.87	2.89	2.04	1.19	1.56	2.16	1.40	28.37
1906	3.29	2.12	3.77	2.28	3.11	4.14	2.73	1.98	8.98	2.30	2.67	1.76	39.13
1907	4.72	0.27	2.02	3.19	2.79	2.72	7.32	5.27	1.76	0.74	1.46	1.49	33.75
1908	1.27	3.33	3.08	2.41	11.29	5.21	5.12	3.98	1.56	1.40	3.08	0.87	42.60
1909	1.54	3.06	2.02	3.92	3.34	3.99	5.06	0.38	3.68	3.77	5.98	3.88	40.62
1910	1.92	1.51	0.73	2.91	4.66	1.97	2.62	0.37	2.80	0.86	0.48	1.13	21.96
1911	2.53	3.51	2.25	4.12	1.53	2.05	4.12	1.70	20.03	2.38	3.00	1.90	49.12
1912	0.60	1.61	1.80	3.98	2.77	1.80	3.94	1.10	2.70	5.47	1.98	0.77	28.52
1913	1.66	2.00	3.91	2.91	6.07	2.49	0.05	1.31	1.89	3.21	2.06	1.04	28.60
1914	1.18	1.10	1.74	2.20	1.86	1.58	0.87	1.45	6.48	2.40	0.92	2.16	23.94
1915	2.65	2.25	0.89	1.69	5.69	4.00	9.58	1.36	5.81	0.52	3.07	....	.....
1916	5.42	0.34	3.16	2.15	7.01	4.18	2.02	1.62	4.52	3.41	1.54	1.42	36.79

MORRISON, WHITESIDE COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1895	....	....	....	....	2.86	3.50	3.28	2.75	5.88	....	....	....	.....
1896	....	....	1.83	4.91	4.34	3.30	6.55	2.99	5.10	1.00	0.97	0.39	.....
1897	2.91	1.73	3.33	2.88	1.95	5.27	3.05	0.89	2.16	0.43	1.40	1.32	27.32
1898	3.01	1.82	4.42	5.11	4.19	2.98	1.68	5.61	2.68	3.38	1.20	0.54	36.62
1899	0.30	1.87	1.94	2.73	7.51	2.68	2.78	3.18	0.96	3.39	1.29	1.95	30.58
1900	1.31	2.56	3.12	3.95	6.33	1.61	5.35	5.03	4.07	2.75	1.31	0.23	37.62
1901	0.82	0.63	2.92	0.49	2.62	3.82	6.42	0.29	2.19	0.83	1.03	1.36	23.42
1902	0.82	1.62	2.46	1.47	6.48	9.60	8.66	5.32	3.99	2.78	2.91	2.45	48.56
1903	1.04	1.47	2.41	4.45	5.49	2.02	7.40	5.78	6.09	3.57	1.05	1.58	42.35
1904	2.53	1.13	3.86	3.18	3.13	1.13	4.04	5.71	3.19	0.60	0.02	2.81	31.33
1905	0.94	2.89	3.13	3.80	6.71	4.03	2.52	3.64	2.81	3.23	1.91	1.48	37.09
1906	2.34	2.24	3.36	3.03	5.27	4.48	4.10	2.91	3.85	1.38	3.17	1.55	37.68
1907	3.98	0.46	1.66	1.74	6.03	5.01	9.19	6.43	5.75	1.44	1.42	1.01	44.12
1908	0.77	3.10	3.47	2.56	6.84	4.33	3.67	3.71	1.01	0.59	2.83	0.50	33.38
1909	2.42	2.43	1.60	6.41	3.58	5.57	3.59	3.14	2.60	2.22	4.50	3.72	41.78
1910	1.82	0.76	0.44	4.09	3.15	0.40	1.08	2.44	3.80	0.64	0.91	0.86	20.39
1911	1.28	3.52	0.82	4.12	2.67	2.19	3.06	6.81	5.57	2.20	5.12	1.90	39.26
1912	0.38	1.05	1.74	2.84	3.35	2.62	4.08	4.37	3.05	4.23	1.25	1.03	29.99
1913	1.00	1.18	2.43	1.70	6.01	4.17	1.59	2.62	2.59	2.76	1.54	0.19	27.78
1914	0.76	0.78	4.60	1.83	5.06	5.41	1.92	0.71	6.10	3.40	0.20	1.83	32.60
1915	1.79	2.59	0.87	0.42	5.13	4.59	7.31	3.81	4.66	0.26	3.12	0.33	34.88
1916	4.95	0.90	1.96	2.12	3.94	5.64	0.22	3.06	3.81	4.43	1.51	2.27	34.81

Values for 1895 are for Tampico, 15 miles distant.
Values from March, 1896, to June, 1901, inclusive, are for Round Grove, 5 miles distant.

OTTAWA, LASALLE COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1856	1.90	0.43	0.14	1.36	6.20	2.11	2.71	1.54	2.38	2.86	3.64	4.82	30.09
1857	0.46	4.45	3.06	1.41	3.65	3.95	3.97	6.10	0.89	2.68	2.96	1.12	34.70
1858	1.65	3.15	2.98	4.55	8.36	6.57	4.82	2.37	3.55	3.97	2.35	2.55	46.87
1859	1.71	0.86	5.24	4.08	3.12	1.68	0.73	3.44	1.66	2.34	2.09	0.94	27.89
1860	2.66	1.59	0.70	1.49	2.20	2.54	2.89	0.79	1.88	0.40	4.03	5.90	27.07
1861	1.22	1.95	2.54	4.97	3.60	4.64	5.23	2.41	5.17	3.57	1.44	2.15	38.89
1862	5.80	1.29	4.16	4.85	3.61	5.61	8.92	6.82	7.55	2.49	2.48	2.13	55.71
1863	....	3.29	3.26	3.26	3.64	....	....	3.11	2.74	4.23	1.78	1.40	.....
1864	2.43	1.64	2.70	3.64	1.79	1.52	2.94	1.85	2.58	1.66	3.29	3.49	29.53
1865	0.45	3.99	3.15	5.48	....	5.17	5.01	5.50	3.89	1.84	0.49	0.59	.....
1866	2.85	2.49	1.97	1.62	2.16	1.57	5.73	3.62	4.72	2.16	0.90	2.97	32.76
1867	1.28	4.55	1.42	1.72	4.64	3.73	4.23	2.41	0.11	0.92	....	1.66	.....
1868	1.07	1.40	5.28	2.60	7.64	2.21	1.96	3.19	3.48	....	....	....	.....
1869	....	1.95	1.38	4.58	7.45	6.27	4.40	4.24	....	1.48	1.88	1.63	.....
1870	5.28	0.90	3.68	0.85	1.15	1.39	1.90	2.26	3.68	4.38	1.42	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1886	....	....	....	....	....	....	....	....	....	1.60	0.60	0.43	.....
1887	1.82	3.25	0.64	0.39	1.08	1.12	1.17	3.06	2.77	2.30	2.17	8.83	28.60
1888	1.80	1.88	3.70	1.28	5.39	2.01	3.58	1.77	0.60	2.71	3.33	2.22	30.27
1889	1.91	1.16	1.77	2.44	4.36	4.61	5.67	2.00	3.92	1.51	3.12	1.80	34.27
1890	1.94	1.40	3.33	1.87	3.99	6.87	0.34	2.72	2.48	3.89	2.06	0.27	31.16
1891	2.86	2.28	2.56	3.96	1.84	3.99	4.45	5.11	1.27	0.56	4.75	1.74	35.37
1892	1.45	1.52	2.70	3.56	13.25	9.80	4.92	0.81	2.56	0.63	2.48	1.84	45.52
1893	2.20	3.03	3.30	5.23	1.95	2.49	1.02	0.77	2.29	1.10	2.18	2.16	27.72
1894	2.38	1.58	2.57	1.51	4.01	3.03	0.80	1.75	7.18	1.63	2.09	1.19	29.72
1895	1.22	0.70	0.82	2.02	1.06	1.02	4.79	2.26	1.47	1.16	5.27	5.77	27.56
1896	1.37	1.65	1.32	3.33	4.24	2.22	8.63	2.43	9.38	0.17	3.48	0.28	38.50
1897	5.98	1.71	4.47	1.88	0.99	6.90	2.99	0.74	1.89	0.46	4.37	1.74	34.12
1898	5.24	2.38	5.21	3.12	6.72	5.80	1.30	4.31	5.90	4.73	2.88	1.42	49.01
1899	0.63	2.10	3.21	1.50	5.08	1.42	5.70	3.02	2.15	2.53	1.46	2.03	30.83
1900	1.60	4.53	2.91	1.53	5.60	1.96	4.53	7.24	2.26	2.24	3.16	0.31	37.87
1901	1.76	2.10	3.51	0.61	2.15	2.67	5.47	0.81	3.20	0.91	1.49	2.09	26.77
1902	0.63	1.41	4.89	2.55	5.64	10.51	10.49	4.40	6.76	1.87	4.29	2.01	55.45
1903	1.13	2.35	3.10	5.08	4.19	3.78	1.94	4.90	6.03	1.43	0.46	1.91	36.30
1904	2.54	1.80	4.87	3.93	3.00	1.89	5.14	3.58	3.27	0.26	0.08	1.86	32.22
1905	1.30	1.93	2.09	5.15	3.68	3.39	1.68	4.12	2.13	1.87	2.01	1.70	31.05
1906	2.07	2.26	2.02	1.63	2.37	2.64	1.45	4.57	5.09	1.23	2.63	1.22	29.18
1907	5.25	0.15	2.55	2.69	4.84	2.50	6.92	4.49	4.94	1.00	1.96	1.79	39.08
1908	0.86	1.53	3.87	3.48	8.17	1.77	3.05	2.03	0.35	0.65	1.79	0.99	28.54
1909	0.98	3.65	1.64	5.19	2.57	3.69	2.95	3.59	4.08	1.71	2.57	3.02	35.64
1910	2.78	0.98	0.42	3.28	5.28	1.25	0.67	3.91	6.23	1.25	0.74	0.98	27.77
1911	1.80	2.13	1.80	3.91	2.64	1.71	1.60	6.28	6.88	2.61	2.28	2.15	35.79
1912	0.27	1.14	1.17	3.30	6.13	2.09	3.28	5.68	2.86	5.26	2.02	1.18	34.38
1913	1.80	3.00	3.87	2.09	6.71	2.36	2.17	2.98	2.10	2.70	1.80	0.59	32.17
1914	1.77	1.10	2.35	1.28	4.06	2.53	0.66	2.33	2.87	3.17	0.40	1.92	24.44
1915	1.86	2.13	1.01	0.75	5.63	2.10	7.30	2.80	4.88	0.86	1.95	0.82	32.09
1916	*5.00	0.59	1.92	0.86	3.90	7.37	0.08	1.05	1.54	4.75	2.48	1.34	30.88

*Interpolated from La Salle, in the same county.

PEORIA, PEORIA COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1855	....	....	....	....	....	....	....	....	....	....	....	3.76	.....
1856	0.80	1.03	0.25	1.72	4.03	1.50	2.83	1.39	0.76	1.66	4.00	6.13	26.10
1857	0.37	5.33	3.84	1.39	2.80	2.77	1.40	5.61	2.16	2.01	1.33	1.50	30.51
1858	1.48	1.95	3.28	6.25	10.64	5.95	5.75	3.24	2.96	3.24	4.85	3.67	53.26
1859	1.50	1.42	5.82	2.60	3.17	2.18	0.67	4.14	2.84	2.15	2.40	1.23	30.12
1860	1.86	2.40	1.13	1.64	2.00	4.95	8.87	2.39	2.00	0.70	3.13	3.08	34.15
1861	1.25	2.46	3.96	4.95	2.19	2.31	2.31	2.78	3.72	2.33	1.09	0.94	30.29
1862	4.27	0.70	2.71	5.03	1.46	3.67	7.74	9.04	5.09	1.61	1.81	5.20	48.33
1863	2.83	3.20	2.61	1.52	2.97	0.45	4.82	2.24	2.51	3.92	0.71	4.49	32.27
1864	1.42	0.41	2.20	4.81	1.88	2.55	2.92	1.56	4.81	1.53	3.82	3.06	30.97
1865	0.22	4.01	3.57	4.27	2.34	1.36	5.77	3.61	8.31	1.67	0.81	1.08	37.02
1866	3.21	1.10	2.54	2.65	2.57	2.61	5.17	3.97	6.50	2.87	0.51	2.05	35.75
1867	1.36	2.88	1.74	1.57	4.40	2.92	2.65	2.26	0.60	1.10	1.93	1.21	24.62
1868	0.77	0.75	5.38	3.18	7.85	1.43	1.47	2.74	4.46	1.41	4.50	1.81	35.75
1869	0.99	2.62	1.71	3.59	6.09	8.35	7.35	3.39	0.74	1.53	3.13	2.63	42.12
1870	2.05	0.33	4.37	0.45	1.62	0.75	0.68	3.26	3.56	4.27	1.21	1.02	23.57
1871	2.45	1.62	3.24	2.58	1.93	3.47	3.76	4.95	0.65	3.37	2.09	2.04	32.15
1872	0.20	0.69	2.50	2.95	2.38	9.76	7.80	4.54	4.13	0.80	2.00	1.07	38.82
1873	3.47	1.29	1.30	4.76	4.78	2.96	4.25	1.25	3.65	2.26	1.46	7.15	38.58
1874	3.04	1.45	1.11	2.90	2.51	1.95	1.46	5.60	1.15	1.00	2.20	0.67	25.04
1875	0.32	2.20	2.05	2.00	4.23	3.00	8.28	1.02	9.63	3.46	0.71	2.39	39.29
1876	2.60	2.00	4.70	2.66	3.94	6.17	5.54	3.14	4.51	4.86	2.68	0.28	43.08
1877	0.92	0.06	3.32	2.86	2.57	9.43	3.01	2.04	2.83	5.68	3.65	3.45	39.82
1878	0.50	2.25	2.10	3.75	4.45	3.49	2.58	4.42	0.97	3.96	0.91	2.08	31.46
1879	1.05	0.97	1.80	2.95	0.93	3.23	3.42	1.88	3.72	2.17	4.93	1.92	28.97
1880	3.38	3.95	3.30	5.94	6.73	2.32	3.17	3.38	3.09	1.75	1.92	0.96	39.89
1881	0.52	3.51	3.52	1.62	3.50	7.20	2.43	1.38	4.05	5.56	4.26	3.50	41.05
1882	1.27	3.21	3.12	2.41	6.34	11.18	2.91	1.92	1.53	3.76	2.08	1.76	41.49
1883	1.31	4.14	0.77	6.18	6.54	4.39	3.57	0.57	2.98	3.57	4.19	1.37	39.58
1884	0.70	3.18	2.17	2.62	5.50	3.87	3.67	4.13	5.76	4.80	2.19	3.21	41.80
1885	2.63	0.87	0.24	4.44	1.70	4.07	4.73	2.64	5.28	2.32	1.04	2.44	32.40
1886	2.41	1.86	2.25	2.75	2.90	3.67	0.47	3.57	4.68	1.81	1.34	0.89	28.60
1887	1.10	5.45	0.94	1.53	1.24	1.53	2.85	2.72	2.53	2.14	1.62	3.65	27.30
1888	1.87	1.66	4.03	1.18	6.72	1.84	6.48	2.30	4.79	2.29	2.67	2.39	38.22
1889	1.70	0.84	1.50	2.79	3.92	6.30	7.64	1.23	2.61	2.28	2.91	1.33	35.05
1890	2.80	1.36	2.73	2.33	2.74	2.42	0.72	2.39	2.12	3.45	1.79	0.41	25.26
1891	1.68	1.90	2.68	3.64	1.97	3.31	2.82	5.71	2.00	0.71	4.08	2.39	32.89
1892	1.25	1.84	2.45	4.54	7.70	6.05	3.08	0.73	2.35	1.20	2.72	1.75	35.66
1893	0.87	2.92	3.01	7.86	4.65	1.82	2.48	0.44	3.02	0.70	2.21	1.74	31.72
1894	2.60	1.48	3.06	2.22	3.58	4.18	1.00	2.50	4.42	1.45	2.92	1.58	30.99
1895	1.32	0.37	1.02	2.89	1.84	1.67	8.72	2.27	4.92	0.67	4.17	5.86	35.72
1896	1.30	1.95	1.05	4.47	5.74	2.23	7.02	4.69	4.86	0.23	2.20	0.40	36.14
1897	5.39	1.19	4.70	2.87	1.29	2.11	4.65	1.02	0.93	0.04	3.48	1.16	28.83
1898	4.08	2.59	5.74	3.02	5.54	3.37	0.47	3.26	6.05	3.00	2.03	0.93	40.08
1899	0.72	1.96	2.97	1.36	6.03	2.60	1.69	1.27	5.24	2.78	2.25	2.12	30.99
1900	1.92	5.64	1.42	1.09	5.54	1.44	2.45	5.39	2.94	2.90	1.87	0.89	32.99
1901	1.98	1.24	4.31	0.81	1.50	4.32	3.97	1.29	2.64	0.90	0.80	2.26	26.02
1902	0.67	1.41	2.71	2.29	2.99	9.60	7.30	7.42	6.78	3.78	2.83	1.54	49.32
1903	0.89	1.70	3.66	5.15	4.22	2.39	4.91	7.22	5.78	2.13	0.85	0.95	39.85
1904	1.87	1.29	4.42	3.48	4.06	2.44	5.58	4.13	6.67	0.10	0.12	1.33	35.49
1905	1.15	1.45	2.00	3.99	4.53	5.13	4.24	1.36	1.78	2.77	2.45	1.60	32.45
1906	1.70	1.85	2.55	2.77	2.88	3.24	2.48	1.59	4.92	1.00	2.42	1.65	29.05
1907	5.39	0.14	2.34	2.82	2.08	3.99	4.89	6.60	2.94	0.35	1.68	1.66	34.88
1908	0.59	3.98	2.50	4.08	7.76	4.09	3.94	2.78	0.82	0.71	1.89	0.82	33.96
1909	1.55	3.67	1.81	7.17	3.72	3.56	4.57	0.79	3.68	3.59	5.53	2.50	42.14
1910	1.97	1.10	0.52	3.56	4.49	0.78	3.23	0.68	3.12	1.69	0.79	1.25	23.18
1911	2.37	2.39	2.64	2.69	1.03	6.64	2.58	1.73	12.30	2.65	3.01	2.13	42.16
1912	0.35	1.21	2.03	6.88	4.39	1.86	5.04	1.67	3.54	4.03	1.56	1.13	33.69
1913	2.18	3.00	3.46	3.54	1.85	2.50	0.46	2.87	2.58	3.11	2.77	0.74	29.06
1914	1.93	1.36	1.60	2.10	2.28	2.45	0.82	2.40	5.55	2.15	0.20	1.81	24.65
1915	1.89	2.71	0.67	1.60	11.49	2.08	6.91	4.78	4.88	0.55	2.29	1.66	41.51
1916	5.95	0.29	2.33	1.60	7.51	2.55	1.14	6.03	3.73	2.93	1.88	1.75	37.69

PONTIAC, LIVINGSTON COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1887	0.92	3.85	1.11	1.20	1.15	0.28	0.13	1.60	1.01	0.93	0.77	3.20	16.15
1888	1.40	1.43	2.38	0.90	5.70	3.85	4.32	0.65	0.47	2.35	1.37	1.20	26.02
1889	1.39	0.97	1.53	1.35	5.50	2.45	4.65	0.11	3.80	1.62	3.10	1.65	28.12
1890	4.18	1.20	3.58	4.15	3.65	5.10	0.75	1.95	0.35	2.61	1.45	0.30	29.27
1891	0.95	2.45	2.88	3.45	0.47	6.07	2.65	3.95	0.20	1.40	4.70	2.40	31.57
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1903	0.80	3.23	2.54	4.94	4.36	1.39	6.35	2.60	3.62	2.76	1.06	1.98	35.63
1904	3.92	1.84	5.73	3.63	2.67	1.95	5.37	2.45	5.79	0.17	0.06	2.14	35.72
1905	1.80	1.89	2.17	3.45	6.33	1.70	1.78	1.82	2.26	2.53	2.26	1.71	29.70
1906	3.07	1.78	3.28	2.18	1.77	2.35	2.39	0.80	3.56	1.61	2.58	2.62	27.99
1907	5.62	0.15	2.74	3.09	3.28	3.00	5.66	4.47	4.59	0.61	2.04	3.05	38.30
1908	1.01	4.52	2.90	4.83	8.72	1.65	2.35	1.25	1.53	0.92	2.61	1.51	33.80
1909	2.58	4.30	1.80	5.96	3.05	2.90	2.29	3.75	2.15	2.33	4.00	3.32	38.43
1910	1.78	0.97	0.20	4.07	5.04	2.14	1.25	4.39	4.10	1.69	0.82	1.73	28.18
1911	2.06	2.13	2.32	3.70	2.26	2.84	1.52	2.25	11.81	2.68	2.95	2.20	38.72
1912	1.00	1.60	2.24	5.50	4.96	2.34	2.95	1.67	3.05	2.26	2.25	0.69	30.51
1913	3.03	1.85	5.13	2.97	7.54	2.30	1.13	3.86	1.81	5.05	1.58	1.24	37.49
1914	1.70	1.16	1.52	2.75	3.05	2.15	0.83	3.02	3.48	1.57	0.18	1.89	23.30
1915	1.64	1.67	1.01	1.60	3.69	2.27	7.81	6.79	7.56	0.49	1.46	1.35	37.34
1916	6.35	0.45	1.72	1.10	4.85	6.55	0.32	3.20	2.34	3.43	1.95	2.50	34.76

ROCK ISLAND ARSENAL, ROCK ISLAND COUNTY, ILLINOIS

1866	....	0.49	2.03	....	3.87	....	....	....	4.05	1.31	0.83	1.82	.....
1867	0.82	2.81	1.31	1.79	5.48	2.89	3.52	3.40	3.61	0.86	2.19	0.57	29.25
1868	0.09	0.51	5.09	5.92	7.76	2.52	2.57	2.26	3.01	1.63	2.45	0.50	34.31
1869	1.49	1.13	0.21	3.29	3.84	7.15	7.98	5.69	1.81	1.32	9.29	2.62	45.82
1870	....	3.95	17.71	0.34	1.26	1.19	1.40	3.70	4.74	2.84	1.04	0.66	.....
1871	3.01	3.25	1.54	2.86	1.04	3.85	1.83	3.81	0.23	3.34	2.29	5.16	32.21
1872	0.38	0.22	1.04	2.00	3.65	2.58	3.80	7.60	3.67	0.16	1.26	0.29	26.65
1873	2.95	0.30	0.46	4.05	3.45	0.95	1.35	0.28	0.52	1.25	1.06	3.20	19.82
1874	3.10	0.45	0.90	1.27	2.93	3.43	1.78	2.64	6.15	0.50	1.03	0.18	24.36
1875	0.20	0.65	0.35	1.10	1.18	5.20	7.37	1.32	4.08	0.85	0.35	4.16	26.81
1876	2.18	2.65	2.87	3.40	6.10	4.40	2.30	3.84	4.05	1.20	2.70	0.20	35.89
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1889	4.20	1.45	2.31	4.18	5.55	4.93	8.59	1.07	4.29	1.15	2.23	1.56	41.51
1890	3.06	1.91	3.20	0.99	5.03	5.28	1.24	2.09	3.40	4.38	1.71	1.20	33.49
1891	2.84	1.01	2.53	3.46	2.71	3.65	3.09	5.74	1.48	1.47	3.47	1.30	32.75
1892	1.31	1.39	....	....	....	....	....	....	....	....	....	....	.....

STREATOR, LASALLE COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1893	....	....	....	6.17	3.21	0.96	....	....	3.00	....	2.80	0.97	.....
1894	1.90	0.44	2.95	1.03	3.62	2.53	....	....	....	....	....	2.10	.....
1895	1.55	0.30	1.40	0.41	0.80	....	6.00	2.60	1.90	1.00	4.54	5.89	.....
1896	1.30	1.15	0.65	2.68	5.98	3.27	5.75	1.52	3.44	0.05	2.07	0.10	27.91
1897	5.65	1.55	4.08	1.88	1.13	6.70	2.71	1.07	1.10	0.23	4.20	1.32	31.62
1898	3.43	1.62	6.93	3.00	6.00	3.24	0.62	2.96	4.20	2.99	2.47	0.77	38.23
1899	1.28	1.82	*2.00	0.45	2.50	1.82	5.22	1.69	2.73	2.47	1.23	1.93	25.14
1900	1.49	3.54	2.85	1.24	2.44	1.63	3.13	7.13	2.56	2.18	2.57	0.84	31.10
1901	1.42	1.40	3.49	0.75	1.24	2.85	3.02	2.56	2.20	0.63	1.38	2.15	23.09
1902	0.79	1.32	4.66	2.17	4.37	10.64	8.59	7.11	5.26	3.24	3.48	1.74	53.37
1903	0.90	2.52	3.79	4.81	2.48	2.07	2.43	4.04	7.60	1.02	0.78	1.78	34.22
1904	2.23	1.55	5.76	3.91	4.46	2.11	4.60	2.39	4.15	0.20	T	1.57	32.93
1905	1.07	1.38	2.20	4.22	4.77	3.01	4.10	2.15	2.39	2.64	1.73	1.41	31.07
1906	2.26	1.99	2.77	1.40	1.79	3.10	1.39	2.25	4.25	1.64	2.75	3.06	28.65
1907	5.64	0.10	3.02	2.92	3.70	3.95	7.61	5.08	5.58	0.51	2.06	1.41	41.58
1908	0.59	3.73	2.53	4.15	7.16	1.69	3.62	0.41	0.39	0.68	2.36	0.92	28.23
1909	1.37	3.45	1.81	6.61	2.76	4.79	2.60	3.31	2.74	2.21	3.78	2.85	38.28
1910	2.25	1.03	0.41	4.20	5.13	2.98	0.81	5.38	4.59	1.43	0.43	1.81	30.45
1911	2.22	1.91	1.77	3.50	2.33	4.24	2.55	4.20	6.77	†3.75	2.86	2.17	38.27
1912	0.44	1.56	1.89	4.62	4.73	1.15	3.08	1.88	3.18	3.61	2.55	0.78	29.47
1913	1.76	2.58	3.64	2.91	5.57	1.87	1.59	3.28	1.21	2.29	2.80	1.89	30.89
1914	1.77	0.91	1.84	1.75	3.34	2.17	0.56	3.05	4.36	2.38	0.28	2.01	24.42
1915	1.51	2.00	0.84	0.99	5.66	1.85	8.60	4.42	6.23	0.99	2.08	1.43	36.60
1916	6.61	0.42	1.84	1.28	5.04	7.01	0.45	3.01	2.77	4.42	2.67	2.68	38.20

*Estimated. †Interpolated from Minonk.

SYCAMORE, DE KALB COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1881	....	....	....	....	3.50	11.40	7.05	0.80	5.10	3.20	3.60	3.75	.....
1882	1.31	1.90	4.85	6.10	3.80	7.90	4.35	2.34	1.94	4.55	2.25	2.25	43.54
1883	2.15	4.95	0.65	3.41	8.55	5.85	5.50	1.95	2.93	6.48	6.63	1.86	50.91
1884	0.71	2.15	2.02	4.06	3.18	4.63	8.84	3.43	3.46	5.76	2.48	4.14	44.86
1885	2.66	1.55	0.55	4.31	1.65	7.04	4.98	9.90	6.10	4.65	2.06	3.05	48.50
1886	4.10	1.85	3.85	5.14	4.24	2.27	0.67	4.29	3.23	2.26	0.96	1.54	34.40
1887	3.93	4.50	0.89	1.08	0.95	1.12	3.12	3.61	3.27	2.80	1.49	3.02	29.78
1888	1.01	1.16	2.59	2.05	5.50	1.27	3.10	4.03	1.09	2.37	1.80	2.16	28.13
1889	1.13	1.16	1.39	3.47	5.17	1.50	4.48	0.86	1.93	0.85	1.80	1.52	25.26
1890	1.64	1.15	1.57	2.58	3.87	7.98	0.42	2.07	1.22	3.48	1.87	1.50	29.35
1891	1.91	1.60	1.95	4.50	2.79	3.55	2.00	2.22	0.37	0.89	4.21	2.37	28.36
1892	1.73	1.21	2.01	4.81	11.77	11.23	2.56	3.56	1.62	0.95	2.13	2.06	45.64
1893	1.83	2.12	2.22	4.59	3.25	5.04	3.65	0.46	3.83	1.13	2.74	2.19	33.05
1894	2.50	1.35	3.26	2.87	3.90	1.79	0.78	0.95	7.88	1.77	1.96	0.74	29.75
1895	1.35	0.30	1.03	1.24	2.52	2.20	3.10	3.06	0.75	0.55	3.71	3.38	23.19
1896	0.50	2.03	1.44	2.74	3.80	1.59	3.60	0.58	8.39	0.26	1.88	0.55	27.36
1897	4.64	1.31	4.31	3.78	1.10	6.04	3.03	1.06	0.44	0.38	3.38	0.81	30.28
1898	3.28	3.57	5.42	1.65	3.20	3.47	1.22	6.47	3.71	4.81	1.76	0.80	39.36
1899	0.37	1.59	2.14	0.96	3.32	1.19	4.04	1.39	1.73	2.44	1.33	1.41	21.91
1900	1.63	3.00	1.96	1.15	2.83	2.22	5.60	11.17	2.79	2.27	2.23	0.53	37.38
1901	1.27	1.19	3.86	0.44	1.63	1.88	4.51	1.06	2.18	0.71	1.32	1.30	21.35
1902	0.70	2.72	3.27	1.96	7.97	9.00	7.83	2.27	4.29	3.10	2.95	2.02	48.08
1903	1.83	1.87	3.10	4.76	3.16	2.70	7.14	5.14	6.88	2.57	0.97	2.38	42.50
1904	1.31	1.52	4.66	2.91	3.51	2.57	4.04	6.49	5.24	0.84	0.03	2.16	35.28
1905	0.50	1.45	2.98	3.14	6.59	4.30	3.20	6.52	1.06	4.61	2.20	1.66	38.21
1906	2.99	3.03	3.06	1.80	4.40	3.17	1.36	3.34	6.09	2.02	3.40	1.84	36.50
1907	3.88	0.30	1.49	2.66	4.59	4.57	4.99	3.28	7.39	1.26	1.42	1.17	37.00
1908	0.79	2.93	3.31	4.60	7.01	4.12	3.06	3.46	1.00	0.86	2.05	1.50	34.69
1909	1.72	1.97	1.60	10.09	2.97	3.27	0.62	7.08	3.95	1.19	5.42	5.27	45.15
1910	1.25	0.77	0.23	3.78	4.81	0.78	1.50	4.22	1.80	2.04	1.10	0.63	22.91
1911	1.47	1.94	0.74	3.21	2.56	2.56	2.65	4.88	6.16	2.91	3.74	1.78	34.60
1912	0.40	0.28	2.50	2.16	3.75	2.34	4.01	4.26	2.75	5.84	1.12	T	29.41
1913	0.38	*1.51	4.52	3.08	5.15	1.94	4.09	2.54	3.23	3.95	1.23	0.48	32.10
1914	1.55	0.90	3.26	0.96	6.75	6.50	0.43	2.48	3.74	2.94	0.52	2.38	32.41
1915	1.45	1.76	0.46	0.54	7.55	5.34	8.01	1.93	4.74	1.74	1.37	0.22	35.11
1916	2.89	0.58	3.25	1.43	3.67	8.89	0.20	1.52	3.86	4.73	2.04	1.05	34.11

*Interpolated from Elgin.

TISKILWA, BUREAU COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1864	....	....	....	....	....	....	....	1.75	3.16	3.16	2.98	3.89	.....
1865	0.26	3.40	3.12	6.14	1.57	4.47	6.96	8.79	11.57	2.90	0.28	0.54	50.00
1866	1.92	2.02	2.38	1.90	1.90	2.80	4.19	5.44	6.79	1.66	0.26	3.06	34.32
1867	1.76	1.27	2.06	2.00	6.62	3.30	1.95	2.48	1.36	0.97	2.40	1.50	27.67
1868	0.48	0.97	5.15	....	....	2.41	2.03	2.08	4.61	1.24	3.57	1.21	.....
1869	1.95	2.47	1.14	3.40	7.78	9.96	6.86	9.37	0.67	0.81	3.88	3.02	51.31
1870	4.15	0.70	5.50	0.60	1.42	0.70	1.91	....	6.64	3.62	1.84	1.52	.....
1871	3.82	2.00	2.72	2.88	2.35	5.90	1.85	....	....	....	3.45	3.47	.....
1872	0.18	0.75	2.96	5.91	6.56	6.31	4.05	9.21	6.33	0.92	1.59	1.28	46.05
1873	4.55	1.06	1.39	6.75	7.25	2.65	5.65	1.32	1.83	2.23	1.40	3.87	39.95
1874	3.05	1.29	1.81	3.27	3.48	4.56	1.78	3.56	5.14	3.40	2.94	0.74	35.02
1875	1.10	2.34	2.38	3.40	4.65	6.18	9.60	2.30	8.53	4.15	0.83	2.60	48.06
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1895	....	....	....	....	2.70	0.70	7.89	2.38	4.44	0.78	3.31	3.89	.....
1896	1.16	1.59	1.01	4.28	4.71	2.81	5.57	2.50	6.70	0.76	1.78	0.17	33.04
1897	5.81	1.27	4.55	2.77	1.42	3.34	2.38	1.48	2.62	0.36	3.36	1.24	30.60
1898	3.76	2.48	6.17	3.50	7.30	2.85	1.17	6.97	4.58	2.68	2.93	1.09	45.38
1899	0.38	1.81	2.83	1.03	5.25	3.89	3.48	1.65	2.55	3.73	1.15	1.63	29.38
1900	1.88	3.85	3.52	1.72	4.23	1.52	2.40	7.76	4.67	2.89	2.03	0.22	36.69
1901	1.36	1.83	3.53	0.80	2.63	2.15	5.12	2.02	2.10	0.70	1.54	1.41	25.19
1902	0.55	1.46	3.29	2.33	5.05	8.19	10.70	5.00	6.25	2.99	3.75	2.12	51.68
1903	0.99	2.95	2.71	5.07	3.72	2.82	2.24	4.26	7.19	2.43	1.27	1.20	36.85
1904	2.58	1.17	3.78	3.32	3.29	1.99	6.78	5.37	3.40	0.23	0.10	1.90	33.91
1905	0.84	1.35	2.73	4.59	5.10	5.72	1.82	2.54	2.51	2.14	2.03	1.60	32.97
1906	2.39	2.28	3.71	2.42	2.96	3.70	2.14	4.38	6.25	1.60	2.97	2.10	36.90
1907	4.47	0.33	2.21	2.83	5.65	3.34	10.17	5.39	3.69	0.66	1.59	1.36	31.69
1908	1.22	3.65	3.62	3.01	9.98	3.80	1.89	1.71	1.14	0.90	2.62	0.83	34.37
1909	1.52	3.19	1.81	4.75	3.82	3.32	3.02	4.50	3.99	2.56	3.67	4.66	40.81
1910	2.57	1.17	0.31	2.66	7.10	1.52	0.91	1.67	2.51	*1.48	*0.54	*1.25	23.69
1911	*2.10	*1.91	1.04	3.44	1.55	2.22	3.27	4.78	6.27	1.71	2.05	2,10	32.44
1912	0.36	1.15	1.94	3.36	4.20	1.81	1.13	2.29	2.53	6.55	2.39	0.75	28.46
1913	1.46	2.51	3.76	1.67	5.75	5.12	0.34	2.04	1.60	2.72	2.40	0.59	29.96
1914	1.27	1.14	1.90	1.45	3.09	2.77	0.58	1.85	3.63	2.77	0.13	1.46	22.04
1915	1.73	2.63	0.83	0.90	6.91	2.28	5.11	4.37	5.06	0.50	2.63	0.67	33.62
1916	5.40	0.71	3.52	1.73	3.25	7.74	0.76	6.81	2.82	4.68	2.41	1.17	41.00

Values from 1864 to 1875, inclusive, are for Wyanet, 6 miles from Tiskilwa.
*Values are for Henry.

WALNUT, BUREAU COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1892	2.30	1.48	3.00	4.06	8.49	7.84	5.41	0.96	3.42	1.06	1.73	1.94	41.69
1893	1.55	1.78	3.13	5.02	1.65	4.54	0.86	0.48	3.38	0.23	2.11	2.05	26.78
1894	2.11	2.10	2.98	1.23	3.57	3.00	0.26	1.35	6.89	1.43	1.52	0.61	27.05
1895	1.92	0.55	0.86	1.02	2.39	0.92	5.41	3.23	2.71	0.64	2.60	3.55	25.80
1896	0.87	1.57	1.51	5.17	4.12	3.81	6.32	2.63	5.94	1.20	2.06	0.17	35.37
1897	5.01	1.45	5.05	3.71	1.25	4.94	1.35	1.33	3.43	0.25	2.27	1.31	31.35
1898	3.96	2.08	5.22	2.78	5.22	3.98	1.20	5.51	4.47	2.63	1.70	0.96	39.71
1899	0.36	1.57	1.99	1.82	6.68	1.69	5.05	2.95	1.91	2.78	0.84	1.57	29.21
1900	1.50	2.78	3.17	1.35	3.83	3.08	6.12	6.60	4.74	3.48	1.64	0.29	38.58
1901	1.03	1.25	2.57	0.51	2.43	4.16	3.53	1.58	2.06	0.82	1.37	1.25	22.56
1902	0.38	1.33	2.09	1.53	6.50	8.89	11.01	4.68	4.99	3.63	1.89	1.81	48.73
1903	1.57	1.88	2.65	4.38	4.59	1.96	5.38	4.53	6.69	2.98	0.53	1.32	38.46
1904	2.22	1.55	2.89	1.69	3.31	1.38	5.34	4.53	3.96	0.37	0.06	2.18	29.48
1905	0.74	1.86	3.63	3.88	5.01	5.20	2.19	4.88	2.77	3.02	1.18	1.42	35.78
1906	2.92	2.87	5.22	2.07	4.17	3.94	1.68	3.07	4.02	1.22	2.79	2.52	36.49
1907	3.97	0.25	2.23	2.57	4.13	3.44	9.53	4.67	4.84	0.51	1.41	0.92	38.47
1908	0.85	3.82	3.34	2.74	9.89	2.90	2.85	4.94	1.26	0.58	2.31	0.66	36.14
1909	1.66	3.91	1.05	5.94	3.14	3.09	1.83	3.09	2.41	2.09	5.24	4.37	37.82
1910	1.86	1.07	0.30	2.42	4.84	0.69	1.34	4.12	4.81	0.91	0.60	1.16	24.12
1911	1.25	2.26	0.78	3.66	2.60	4.56	3.11	5.64	7.80	2.90	3.76	1.95	40.27
1912	0.17	1.72	1.69	3.01	1.99	3.75	2.43	4.63	4.09	5.26	2.18	1.26	32.18
1913	1.30	2.15	2.95	2.06	5.00	3.27	1.27	1.51	2.02	2.88	1.76	0.39	26.56
1914	1.51	1.04	2.75	0.65	5.24	5.57	1.61	0.87	5.30	3.36	0.14	1.88	29.92
1915	1.85	2.75	1.10	0.65	6,29	2.86	5.84	4.89	4.13	0.44	3.18	0.58	34:56
1916	5.25	0.45	2.82	1.75	3.80	5.97	0.65	2.45	2.87	5.11	1.86	1.66	34.64

PRECIPITATION FOR CENTRAL-NORTHERN DISTRICT
AVERAGE OF ALL STATIONS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1856	1.35	0.73	0.20	1.54	5.12	1.81	2.77	1.47	1.57	2.26	3.82	5.48	28.13
1857	0.42	4.89	3.45	1.40	3.23	3.36	2.69	5.86	1.53	3.03	2.29	1.21	33.33
1858	1.77	2.15	2.88	5.33	8.61	5.86	5.42	3.15	3.84	3.71	3.61	2.88	49.21
1859	1.68	1.17	5.69	3.19	2.99	2.25	1.14	3.37	2.52	2.01	2.52	0.97	29.50
1860	2.26	1.87	0.83	1.80	2.92	3.54	5.95	1.62	2.30	0.55	3.58	3.98	31.20
1861	1.17	2.39	3.25	4.51	2.81	3.55	3.70	2.57	4.96	3.42	1.17	1.55	35.05
1862	4.51	0.81	3.08	4.89	2.78	5.00	7.41	7.18	6.07	1.69	2.10	3.40	48.92
1863	2.84	3.05	2.56	2.39	3.41	0.45	2.78	2.38	2.37	4.30	0.94	2.77	29.24
1864	1.69	0.87	2.68	4.16	1.82	2.72	3.09	1.84	3.00	2.18	3.08	3.58	30.71
1865	0.85	3.41	3.13	5.00	2.01	3.66	5.76	5.57	7.27	2.21	0.31	0.65	39.83
1866	2.63	1.27	2.10	1.95	2.13	2.14	4.58	4.58	6.21	2.07	0.58	2.54	32.78
1867	1.27	2.70	1.70	1.85	5.60	3.00	2.50	2.77	1.43	0.98	2.01	1.21	27.02
1868	1.09	0 86	5.56	4.25	6.60	2.13	1.91	3.09	4.32	1.31	3.51	1.17	35.80
1869	1.44	2.22	1.23	2.82	5.70	7.11	6.55	6.00	1.07	1.17	4.20	2.46	41.97
1870	3.52	1.44	6.17	0.74	1.86	1.04	1.88	3.23	4.36	4.26	1.27	1.18	31.58
1871	3.05	2.02	2.64	2.67	2.60	4.42	2.42	3.96	0.58	3.03	2.78	2.80	32.97
1872	0.32	0.52	2.14	3.61	3.73	5.14	4.14	6.39	5.30	0.78	1.41	0.88	34.36
1873	3.39	0.69	1.04	4.96	5.24	1.86	3.55	1.46	2.17	1.96	1.24	4.53	32.09
1874	3.29	1.17	1.37	2.75	2.84	3.61	1.66	3.65	4.90	1.67	2.42	0.61	29.94
1875	0.50	1.52	1.36	2.29	3.38	4.67	8.11	1.78	5.42	2.51	0.64	2.79	34.97
1876	2.76	2.65	3.74	3.36	4.10	5.18	4.36	2.78	4.23	2.01	2.77	0.44	38.38
1877	1.21	0.06	3.48	3.08	2.46	7.21	3.17	2.24	1.65	5.62	3.90	2.80	36.88
1878	0.58	1.66	2.68	4.50	5.07	3.43	2.82	5.02	1.34	3.89	0.73	1.93	33.65
1879	0.76	1.07	1.82	2.14	2.88	3.66	3.75	2.28	1.83	2.15	4.31	1.64	28.29
1880	3.48	2.89	2.73	4.71	5.62	4.04	3.70	4.75	3.03	1.95	1.38	1.04	39.32
1881	0.96	5.12	3.43	1.56	2.44	7.77	3.64	0.82	4.41	6.76	3.96	2.76	43.63
1882	1.28	2.00	3.34	4.55	5.19	7.80	3.82	3.80	1.35	3.64	1.83	1.99	40.59
1883	1.81	4.71	0.62	4.09	6.57	4.56	4.48	1.14	1.90	5.78	5.04	1.68	42.38
1884	0.96	2.66	2.98	2.63	3.25	3.17	5.43	3.28	3.74	5.19	1.97	3.97	39.20
1885	2.58	1.54	0.35	3.68	2.37	4.28	3.32	7.68	4.45	3.95	1.56	3.09	38.85
1886	3.00	1.73	3.02	3.01	4.58	2.36	0.94	2.89	4.56	1.99	1.17	1.11	30.36
1887	2.37	4.90	1.00	1.14	1.79	1.49	2.57	3.37	3.35	2.62	1.75	3.96	30.25
1888	1.70	1.51	2.98	1.63	6.59	2.56	3.82	2.94	1.39	2.73	2.95	2.28	33.08
1889	1.78	1.22	1.60	2.98	4.77	4.28	6.15	0.97	3.33	1.58	2.58	1.78	32.97
1890	2.90	1.56	2.68	2.54	4.24	5.86	0.97	2.27	1.97	4.08	1.68	0.73	31.48
1891	2.09	1.73	2.50	3.61	2.27	3.98	2.95	4.49	1.06	1.04	4.12	1.92	31.76
1892	1.70	1.88	2.58	4.24	9.45	9.38	3.63	1.66	2.16	0.93	2.17	2.04	42.32
1893	1.62	3.16	2.73	5.35	3.01	3.13	2.04	0.50	2.93	1.08	2.40	1.84	29.79
1894	1.98	1.52	2.77	1.95	3.24	2.76	0.59	1.66	6.22	1.45	1.64	1.08	26.86
1895	1.49	0.44	0.97	1.56	2.36	1.65	5.74	3.18	2.86	0.87	3.60	4.90	29.62
1896	1.05	1.64	1.13	3.72	5.00	2.93	3.03	3.17	5.86	0.85	2.13	0.30	30.81
1897	4.94	1.45	3.96	2.93	1.29	4.30	2.87	1.08	1.52	0.31	3.24	1.40	29.29
1898	3.76	2.16	5.25	2.70	5.48	4.37	1.28	5.52	4.56	3.50	2.15	1.10	41.83
1899	0.53	1.64	2.31	1.29	5.55	2.48	3.99	2.09	2.36	2.79	1.32	1.97	28.32
1900	1.56	3.51	2.62	1.44	4.18	1.85	4.09	5.90	3.17	2.45	2.55	0.37	33.69
1901	1.35	1.39	3.28	0.73	1.82	3.13	3.88	1.32	2.46	1.06	1.15	1.60	23.17
1902	0.56	1.44	3.33	2.26	5.37	10.11	8.49	4.76	5.35	2.71	2.85	2.02	49.25
1903	1.11	2.14	2.72	4.67	3.90	2.56	4.57	5.08	5.82	2.25	0.85	1.40	37.07
1904	2.26	1.24	4.04	2.97	3.21	1.91	5.08	4.38	4.57	0.69	0.09	1.84	32.28
1905	0.92	1.60	2.37	3.93	5.01	4.35	2.82	3.58	2.45	2.64	2.05	1.39	33.11
1906	2.49	2.16	2.72	1.94	3.08	3.26	2.80	3.44	5.01	1.70	2.72	2.13	33.45
1907	4.48	0.25	2.43	2.44	3.80	3.42	6.41	5.29	4.55	0.82	1.65	1.70	37.24
1908	0.99	3.25	3.15	3.33	7.80	2.84	3.33	3.50	1.19	0.86	2.44	0.97	33.65
1909	1.75	3.21	1.61	6.24	3.16	4.07	2.83	3.25	3.06	2.25	4.42	3.58	39.43
1910	2.05	0.97	0.83	3.44	4.89	1.41	1.66	3.18	3.35	1.29	0.70	1.11	24.88
1911	1.62	2.39	1.46	3.62	2.50	3.03	2.83	4.41	3.35	2.80	3.14	2.01	33.16
1912	0.53	1.21	1.81	3.64	4.02	2.43	3.23	3.10	2.90	4.45	1.80	0.91	30.03
1913	1.58	2.05	3.51	2.43	5.42	2.90	1.68	3.05	1.95	3.03	1.73	0.83	30.16
1914	1.59	0.88	2.35	1.51	3.94	3.86	1.06	2.31	4.40	2.50	0.83	1.90	26.63
1915	1.76	2.17	0.76	1.00	6.21	2.95	7.95	3.65	5.22	0.69	2.38	0.97	35.71
1916	5.14	0.52	2.41	1.59	4.62	6.20	0.72	2.45	3.00	4.13	1.95	1.89	34.62

PRECIPITATION FOR CENTRAL DISTRICT BY STATIONS

ALEXANDER, MORGAN COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1887	0.89	2.48	1.20	1.50	2.96	....	....	....	....	0.30	1.76	3.03	.....
1888	2.82	1.82	2.24	1.04	5.54	4.21	6.30	1.53	2.05	2.15	2.00	2.64	34.34
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1895	....	....	....	....	....	2.48	6.55	1.99	3.82	0.28	2.78	6.82	.....
1896	1.19	1.69	0.82	2.49	4.27	4.63	7.50	0.89	5.49	1.98	1.09	0.22	32.26
1897	6.05	0.83	4.42	4.35	3.39	4.52	2.41	2.20	0.24	0.33	3.50	2.42	34.66
1898	4.21	2.81	5.25	3.15	5.83	5.14	2.28	3.17	5.19	3.80	2.56	1.19	44.58
1899	0.96	2.19	2.05	1.18	9.15	1.91	1.34	3.92	4.29	3.07	2.81	1.48	34.35
1900	1.10	3.46	1.47	1.13	2.75	3.09	2.74	3.69	5.29	2.86	3.05	0.24	30.87
1901	2.33	1.44	2.75	1.34	0.70	2.23	1.44	2.84	1.54	2.00	0.88	2.15	21.64
1902	0.70	0.97	3.05	3.26	2.19	7.01	3.27	5.38	4.01	2.29	3.08	2.45	37.66
1903	1.07	2.93	2.67	3.67	3.42	5.20	3.54	2.90	3.57	2.12	0.78	1.09	32.96
1904	1.74	1.40	4.51	5.26	3.56	4.90	3.74	3.84	3.86	0.27	0.05	0.68	33.81
1905	2.67	0.88	1.75	1.82	3.51	3.61	4.33	4.58	3.98	3.67	1.43	1.42	33.65
1906	1.72	2.47	2.98	2.22	4.20	2.98	0.89	5.03	3.23	0.95	3.02	2.84	32.53
1907	5.26	0.26	4.23	2.58	2.33	2.94	8.57	7.78	1.09	1.55	1.25	2.58	40.42
1908	1.27	3.07	2.08	4.97	7.78	3.14	2.31	1.21	1.40	0.22	1.81	1.29	30.55
1909	2.10	3.81	1.03	4.19	6.14	2.24	6.11	0.66	3.89	3.57	4.54	1.50	39.78
1910	1.49	0.84	0.04	2.69	5.25	3.13	2.56	3.62	5.78	1.72	1.14	0.80	29.06
1911	1.74	1.26	1.55	4.21	2.25	0.47	1.91	3.58	12.12	2.03	2.47	1.84	35.43
1912	0.68	1.49	4.02	4.77	5.27	4.64	2.00	3.38	1.62	3.53	1.56	0.53	33.49
1913	3.18	1.56	5.46	2.97	1.66	3.49	1.08	1.79	3.04	3.07	3.60	0.67	31.57
1914	1.84	1.59	1.70	2.47	1.27	1.74	1.14	3.58	3.91	3.63	0.62	2.22	25.71
1915	2.13	2.16	0.80	2.09	7.72	6.26	7.57	5.09	5.12	0.97	2.22	2.80	44.93
1916	4.67	1.00	1.92	1.18	5.21	3.95	1.41	4.69	2.74	1.51	2.14	1.01	31.43

*Values for 1887 and 1888 are for Jacksonville, 10 miles distant.

ASTORIA, FULTON COUNTY, ILLINOIS

1898	....	....	....	....	....	....	....	....	6.68	2.22	2.47	0.97	.....
1899	0.89	1.99	2.75	1.14	8.38	2.58	4.25	3.00	4.26	3.43	1.96	2.02	36.65
1900	2.00	6.99	1.17	1.09	2.72	1.30	1.82	3.39	3.53	2.90	1.16	0.84	28.91
1901	2.30	0.97	3.07	1.40	0.58	3.86	2.65	0.70	2.63	0.71	0.82	2.68	22.37
1902	1.70	1.68	4.08	2.52	3.32	8.71	4.83	5.58	3.03	2.77	2.64	2.77	43.63
1903	1.36	3.13	2.81	5.36	4.44	3.50	4.03	4.43	4.60	3.15	1.27	2.80	40.88
1904	4.15	1.07	4.84	4.35	5.00	4.16	5.42	2.77	5.33	0.38	0.14	1.90	39.51
1905	1.61	2.78	1.95	3.53	2.75	2.83	2.51	4.34	3.82	2.93	2.10	1.71	32.86
1906	2.16	1.29	3.90	3.21	2.18	3.98	0.71	3.50	5.60	1.37	2.20	1.76	31.86
1907	6.04	0.36	2.59	3.10	2.75	3.51	7.38	6.33	2.03	0.51	1.78	1.74	38.12
1908	1.03	5.00	1.48	5.09	8.06	3.14	2.97	1.46	1.18	0.65	2.51	1.00	33.57
1909	2.10	3.81	1.98	5.98	5.15	6.51	4.73	2.18	4.03	2.74	4.19	2.46	45.86
1910	1.73	1.16	0.40	2.86	6.33	2.82	2.65	1.16	4.51	1.92	1.67	1.16	28.37
1911	2.62	2.27	3.03	3.75	1.14	4.01	2.90	2.26	14.22	2.66	2.33	2.92	44.11
1912	0.59	1.90	4.74	5.93	4.42	2.78	1.50	3.28	2.96	3.64	1.97	0.97	34.74
1913	2.21	3.19	4.26	3.55	1.63	3.66	0.42	0.88	2.12	2.30	2.75	1.27	28.24
1914	1.39	3.04	2.55	1.39	1.27	2.98	1.14	3.20	7.04	1.81	0.07	2.44	28.32
1915	2.85	2.35	1.00	1.89	7.11	4.80	10.08	3.52	7.00	0.48	2.92	2.14	46.14
1916	6.91	0.46	2.38	1.74	7.92	1.67	0.23	5.05	1.78	1.68	1.78	2.10	33.70

BLOOMINGTON, MCLEAN COUNTY, ILLINOIS

1886	2.00	1.46	1.81	1.87	2.49	3.71	....	1.85	4.35	0.78	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1892	....	2.31	1.48	6.41	8.27	6.86	4.68	1.16	2.70	1.25	2.62	1.21	.....
1893	1.36	3.13	3.11	8.34	5.40	0.80	1.16	0.15	2.70	0.74	1.93	1.47	30.29
1894	2.32	1.93	3.37	2.53	3.21	1.89	1.34	0.91	5.59	†0.50	2.52	1.86	27.97
1895	1.26	0.39	1.68	2.55	1.13	1.75	6.71	5.12	4.28	0.61	3.74	7.62	36.84

†Estimated from surrounding stations.

BLOOMINGTON, MCLEAN COUNTY—*Concluded*

Year	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1896	0.82	2.55	2.11	2.02	6.79	3.90	6.68	4.75	5.40	0.16	2.95	0.53	38.66
1897	5.41	1.77	4.09	3.92	1.90	3.49	3.91	1.50	2.08	0.48	5.00	2.00	35.55
1898	4.00	1.77	5.65	2.66	9.42	4.02	4.40	1.85	6.49	4.31	2.28	1.92	48.77
1899	1.52	2.20	4.72	0.82	4.06	4.05	1.92	2.15	1.98	2.69	1.67	2.15	29.93
1900	1.23	5.94	2.60	1.85	5.40	2.49	3.38	3.38	1.55	2.62	3.96	0.65	35.05
1901	1.70	1.84	4.04	0.94	2.09	4.79	1.96	1.07	1.87	2.14	1.11	3.08	26.63
1902	0.90	1.75	4.45	2.43	2.07	12.45	7.97	5.81	4.91	2.70	2.75	2.24	50.43
1903	1.31	3.32	3.24	5.76	4.01	3.25	4.68	2.04	2.75	1.48	1.47	2.49	35.75
1904	3.71	1.85	5.28	4.45	3.20	1.40	3.39	2.95	5.65	0.52	0.19	1.53	34.12
1905	1.37	1.82	2.18	5.11	5.56	3.44	4.06	2.96	3.59	2.89	2.65	1.89	37.52
1906	2.66	1.57	2.89	2.33	2.88	3.96	1.27	4.30	4.30	1.85	3.80	3.68	35.49
1907	5.18	0.07	4.50	3.54	2.85	5.74	6.25	6.25	2.69	1.33	2.17	3.10	43.67
1908	1.20	3.80	3.12	7.78	10.17	1.58	2.10	1.17	0.45	0.50	2.48	1.47	35.77
1909	1.77	5.09	1.78	5.94	3.79	4.63	3.15	2.51	2.85	2.98	4.28	2.01	40.28
1910	1.84	1.03	0.61	3.84	5.31	1.70	2.91	0.70	5.39	1.23	0.64	1.29	26.49
1911	1.67	1.51	2.34	2.71	1.73	1.66	2.80	2.46	10.25	2.58	3.71	2.66	36.08
1912	0.77	1.60	2.42	6.36	4.29	3.19	5.25	5.01	1.35	3.42	2.32	0.85	36.83
1913	3.38	1.40	5.78	3.38	2.88	4.55	1.27	2.76	2.27	4.24	2.69	0.80	35.40
1914	2.13	1.59	1.20	2.66	4.99	1.70	1.05	3.29	2.36	2.09	0.25	2.26	25.57
1915	2.03	1.99	1.12	1.90	5.51	1.64	7.87	4.69	7.55	0.87	1.24	2.17	38.58
1916	6.19	0.70	2.12	1.65	8.13	4.57	0.50	2.10	2.94	4.23	1.96	2.12	37.21

CARLINVILLE, MACOUPIN COUNTY, ILLINOIS

1856	1.50	....	....	....	....	6.56	2.64	5.80	8.50	3.51	1.78	0.80	.....
1857	1.28	2.40	1.70	1.40	1.40	2.40	1.00	1.50	0.70	0.40	2.30	1.30	17.78
1858	1.80	1.80	1.90	2.10	3.20	3.26	5.35	0.36	1.81	3.80	3.52	2.37	31.27
1859	1.97	3.54	....	....	....	....	....	....	....	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1883	1.17	7.42	1.47	4.33	3.80	5.00	5.26	1.37	0.10	6.30	4.07	2.46	42.75
1884	2.47	4.11	3.79	2.33	4.27	3.96	2.30	2.56	7.19	2.33	1.86	5.80	42.97
1885	5.19	0.87	0.42	4.27	1.98	8.22	2.29	3.96	5.73	4.89	1.35	3.06	42.23
1886	6.10	1.39	2.86	....	6.30	7.58	0.16	2.94	....	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	
1891	0.70	1.93	2.39	2.08	2.56	3.48	1.27	5.34	0.62	0.94	5.25	1.08	27.64
1892	1.52	3.77	2.42	9.34	9.90	5.72	4.13	1.91	2.28	1.78	4.42	1.69	48.88
1893	0.37	5.72	3.68	9.23	4.59	4.10	1.84	0.51	2.57	1.69	1.37	1.45	37.12
1894	3.09	2.77	3.15	3.12	2.33	1.42	1.77	1.20	5.28	1.07	3.46	1.90	30.56
1895	1.08	1.02	1.60	2.08	1.42	3.16	5.58	2.14	3.43	0.42	2.91	6.75	31.59
1896	1.28	2.76	1.51	2.48	8.11	6.60	6.53	4.63	3.87	1.35	2.01	0.43	41.56
1897	3.91	1.62	6.72	5.85	2.66	3.91	3.33	1.65	T	0.21	5.06	2.89	37.81
1898	4.98	1.96	7.49	4.30	7.58	3.66	3.68	2.68	5.39	4.60	2.63	2.16	51.11
1899	1.79	2.30	3.24	1.27	7.01	1.71	2.54	6.48	2.29	3.91	2.30	2.38	37.22
1900	0.61	4.70	1.72	1.36	4.85	4.88	5.99	1.42	5.03	2.42	2.43	0.95	36.36
1901	1.70	1.81	4.15	2.56	0.86	3.65	0.72	1.83	0.83	2.63	1.49	4.54	26.77
1902	1.14	0.86	4.18	2.44	3.87	10.82	1.82	5.43	3.76	3.06	3.23	3.39	43.50
1903	1.57	3.76	2.18	5.62	3.17	3.75	3.89	3.38	3.69	1.50	0.54	1.75	34.80
1904	2.64	1.09	8.60	6.88	2.93	3.86	9.51	3.57	4.11	0.43	0.08	1.02	44.72
1905	2.39	1.17	2.04	3.68	4.26	1.20	7.44	4.65	3.88	5.14	1.68	2.18	39.71
1906	3.12	3.06	4.20	2.60	2.33	2.17	7.73	5.86	4.96	1.97	3.94	2.57	44.51
1907	5.57	0.57	2.67	3.21	4.36	5.01	5.59	3.77	0.63	1.52	1.78	2.45	37.13
1908	1.56	4.81	2.41	5.11	9.08	3.42	2.36	1.35	2.28	0.23	3.37	1.70	37.68
1909	2.58	4.04	1.87	6.02	4.75	4.65	5.41	0.47	4.76	3.15	3.76	1.99	43.45
1910	1.92	2.20	0.15	4.89	6.52	3.73	5.89	1.37	7.48	2.57	0.44	1.66	38.82
1911	1.80	2.14	1.75	4.93	2.49	0.90	2.30	5.76	5.98	3.49	2.18	2.17	35.89
1912	0.92	1.27	5.05	8.60	3.22	1.65	2.84	2.50	1.98	2.66	3.06	0.32	34.07
1913	3.86	1.09	6.06	3.31	1.28	1.01	1.84	1.97	3.80	2.86	4.02	0.85	31.90
1914	2.80	2.74	*0.50	3.47	0.73	1.43	1.49	2.94	2.99	4.40	0.92	1.94	26.35
1915	2.05	1.99	0.58	3.00	8.13	6.71	5.41	11.09	2.75	0.79	2.01	3.52	48.03
1916	6.87	1.02	1.42	1.81	3.89	5.14	1.22	7.36	2.13	2.01	2.19	1.26	36.32

Data for 1856 to 1859, inclusive, are for Brighton, 21 miles distant.
Data for 1883 to 1886, inclusive, are for Bunker Hill, 17 miles distant.
*Interpolated from Hillsboro.

CHARLESTON, COLES COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1870	....	....	....	1.92	2.63	2.86	4.40	4.34	0.66	3.46	2.01	1.85	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
*1880	6.38	6.37	6.00	6.00	7.00	2.75	3.00	3.38	2.50	2.10	2.50	2.70	50.68
1881	*1.45	5.25	*3.90	2.00	*1.38	*5.75	1.12	*0.87	3.95	7.30	8.20	3.50	44.67
1882	2.90	*8.60	5.10	3.81	5.80	7.70	1.82	*5.94	1.60	3.64	2.04	2.80	51.75
1883	1.20	9.10	*1.28	*3.03	*4.14	*3.94	*4.64	*1.78	*0.80	*9.40	*4.73	*2.26	46.30
*1884	0.90	5.44	2.75	4.16	5.00	6.87	3.65	2.20	4.70	2.80	1.83	5.45	45.75
1885	*2.25	2.56	0.25	4.74	3.10	4.98	2.83	6.47	4.49	3.24	2.61	3.34	40.86
1886	2.80	1.04	3.32	2.73	3.56	2.69	3.66	2.90	4.02	0.74	2.86	1.92	32.24
1887	1.02	3.80	3.40	2.60	3.51	0.07	0.56	2.30	3.32	0.97	7.06	4.75	33.36
1888	2.97	2.70	3.12	2.43	4.82	6.77	2.35	3.25	1.42	2.37	4.35	2.43	38.98
1889	1.80	1.63	1.25	0.90	4.19	†7.50	5.65	1.53	†2.90	2.01	†4.60	†1.00	34.96
1890	....	3.41	3.37	2.66	3.40	6.75	6.98	1.87	2.22	2.19	1.93	1.13	.....
1891	0.91	2.82	3.97	2.51	*0.60	*4.25	*1.88	*4.95	1.43	1.47	5.59	1.90	32.28
1892	1.13	5.65	1.29	10.11	10.90	3.81	3.35	2.72	*1.20	*0.85	*4.75	*0.90	46.66
*1893	1.08	2.71	....	....	4.60	2.00	4.35	1.21	3.87	....	2.60	0.59	.....
*1894	1.53	1.46	3.33	1.81	1.02	2.25	3.84	2.23	4.60	0.39	3.24	1.72	27.42
*1895	0.57	0.71	1.04	2.36	0.73	2.86	3.37	†3.26	†2.74	0.60	2.61	3.36	24.21
1896	1.02	1.99	1.85	1.30	6.41	8.12	10.04	3.18	6.53	0.49	3.82	1.08	45.83
1897	4.47	2.28	5.26	6.41	2.93	6.60	1.96	0.39	1.67	0.42	5.42	3.05	40.86
1898	4.44	1.38	8.90	3.59	4.79	2.79	1.93	3.14	4.46	4.14	1.66	1.80	43.02
1899	2.97	2.55	2.75	0.67	6.86	2.56	0.71	1.41	0.89	4.13	2.95	2.90	31.35
1900	0.45	4.52	1.99	1.79	4.00	4.10	*4.76	4.73	3.22	3.68	2.81	1.23	37.28
1901	1.39	2.30	3.82	*2.18	2.87	*5.95	*1.20	*1.07	*1.46	*3.45	1.62	3.17	30.48
1902	0.97	1.96	3.67	2.33	3.46	7.78	3.78	4.24	4.98	1.99	2.52	3.94	41.62
1903	1.68	2.97	1.77	4.41	0.68	5.55	5.32	5.57	1.94	2.68	1.47	2.04	36.03
1904	3.92	1.20	9.42	4.54	4.80	1.96	3.67	4.93	5.80	0.80	0.18	1.84	43.06
1905	1.82	1.49	1.80	3.00	4.29	1.78	7.19	1.53	2.31	5.53	1.85	2.36	34.95
1906	3.31	1.54	4.80	1.32	3.12	2.98	2.92	1.96	4.18	1.41	4.34	3.68	35.56
1907	4.72	0.34	4.42	2.85	2.79	3.75	7.10	3.59	0.72	2.19	2.60	3.42	37.99
1908	1.28	5.10	3.05	3.60	6.96	3.42	2.94	0.85	1.10	0.18	3.51	1.38	33.37
1909	2.21	4.59	2.05	7.83	3.24	4.00	9.05	1.12	3.35	2.80	3.14	2.63	46.01
1910	2.01	2.92	0.40	2.09	3.84	2.43	7.37	3.75	3.81	4.53	3.42	1.14	37.71
1911	3.46	1.62	2.31	5.30	0.52	1.74	1.47	3.19	10.25	3.54	2.84	1.77	38.01
1912	1.04	2.06	4.85	4.29	3.15	3.07	2.25	4.47	3.57	1.94	1.22	1.51	33.42
1913	4.93	1.42	7.21	2.65	0.61	1.42	0.75	†1.68	†3.72	4.63	3.89	0.64	33.55
1914	2.41	2.35	1.17	2.47	0.71	0.82	1.54	6.16	1.05	4.02	1.10	1.60	25.40
1915	2.71	2.39	0.90	1.39	7.88	4.11	7.11	6.77	2.40	1.06	1.72	4.24	42.68
1916	9.37	1.03	1.45	1.18	3.70	4.61	1.38	2.65	3.34	2.10	1.88	4.03	36.72

†Estimated from surrounding stations.

*Values (including all of years 1880, 1884, 1893, 1894, and 1895) are for Mattoon, 11 miles distant.

DECATUR, MACON COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1870	2.85	0.95	2.97	1.50	0.80	1.50	1.50	4.00	2.60	3.30	1.68	2.25	25.90
1871	4.60	1.65	3.05	....	2.35	1.90	1.85	1.05	0.25	2.50	1.95	1.15	.....
1872	1.10	1.25	2.82	2.00	2.85	7.50	4.60	1.55	2.61	....	0.90	1.45	.....
1873	3.30	2.65	0.65	6.40	2.95	1.65	3.80	....	2.90	1.95	2.40	2.75	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1886	2.50	0.90	2.60	1.60	3.80	6.40	0.30	5.80	5.70	0.20	2.20	0.85	32.85
1887	....	....	....	....	....	....	....	1.95	....	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1892	....	....	....	4.20	5.24	....	3.11	1.84	2.95	T	5.46	T	.....
1893	0.95	....	3.82	....	....	....	....	....	....	....	....	1.41	.....
1894	1.83	2.39	2.79	3.06	1.90	2.23	2.33	1.64	2.94	0.42	1.77	2.65	25.95
1895	1.19	0.94	1.18	2.75	1.07	4.40	3.42	1.35	4.47	0.55	3.12	6.47	30.91
1896	0.97	2.91	1.44	1.56	4.75	4.00	7.12	3.00	5.80	0.66	2.81	0.32	35.34
1897	3.83	1.23	5.08	3.87	3.21	4.22	3.08	1.40	0.41	0.28	4.57	2.54	33.67
1898	5.18	2.71	9.85	3.36	5.74	2.39	1.07	2.16	5.47	5.34	2.96	1.68	47.91
1899	1.89	2.43	2.58	0.59	7.01	2.11	1.02	2.56	1.50	4.20	2.01	2.37	30.27
1900	0.59	5.89	1.84	1.46	4.78	4.18	7.40	4.71	4.34	1.33	3.48	0.92	40.92
1901	1.78	1.17	3.28	1.98	2.00	5.33	0.49	0.86	1.27	3.18	1.54	4.43	28.26
1902	1.06	1.42	3.93	2.26	2.80	9.03	2.43	7.01	4.98	2.08	2.45	3.83	43.28
1903	1.60	4.13	2.48	4.84	3.66	2.61	4.57	5.16	2.67	4.07	1.74	2.16	39.69
1904	2.78	1.33	7.29	3.39	2.67	2.18	4.44	5.55	9.48	0.18	0.07	1.84	41.15
1905	2.02	1.72	1.56	3.11	4.54	1.69	3.82	1.44	3.05	4.76	1.70	1.90	31.31
1906	3.04	1.90	4.93	3.02	6.73	1.78	3.45	5.35	3.47	2.46	4.63	3.51	44.27
1907	7.47	0.30	4.75	2.94	2.89	4.29	7.08	7.36	2.08	1.01	2.07	2.89	45.08
1908	1.64	4.29	3.87	4.54	10.23	3.81	2.25	1.25	1.27	0.71	2.09	1.67	37.62
1909	2.43	4.31	1.27	5.58	5.30	3.14	6.18	2.20	2.79	3.59	3.13	2.40	42.32
1910	1.95	1.72	0.58	3.00	7.16	3.27	3.23	3.81	3.94	2.20	2.84	1.98	35.68
1911	2.67	1.50	1.83	5.11	3.60	2.44	1.45	4.08	12.00	2.59	3.31	1.41	41.99
1912	1.23	1.64	4.60	6.80	3.25	3.41	2.67	4.12	1.50	3.22	2.09	0.97	35.50
1913	5.19	1.28	6.87	3.55	1.12	2.90	1.40	2.18	3.74	3.65	3.68	1.62	37.18
1914	2.69	3.03	1.00	3.85	0.53	0.61	2.50	2.86	3.26	1.74	0.64	2.39	25.10
1915	1.91	2.34	1.34	2.77	6.80	3.08	8.30	5.27	3.48	0.72	1.18	3.25	40.44
1916	6.17	1.16	1.59	1.58	5.28	2.72	0.11	2.72	2.89	2.25	2.08	1.53	30.08

GRAFTON, JERSEY COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1894	....	....	....	2.88	2.03	1.94	1.35	2.15	3.75	1.89	1.90	3.04	.....
1895	0.33	0.38	1.58	1.30	2.59	2.96	7.51	1.92	2.78	0.53	4.61	7.28	33.77
1896	1.45	2.47	1.69	2.80	6.46	7.03	5.09	1.93	3.37	1.16	1.02	0.50	34.97
1897	2.87	2.01	6.97	6.51	1.17	4.99	3.78	1.24	0.11	0.07	3.81	2.72	36.20
1898	5.90	1.30	8.01	3.18	9.08	3.49	5.08	2.08	4.58	4.35	2.31	1.34	50.55
1899	1.12	2.52	3.73	2.91	8.02	2.58	2.27	3.31	1.46	4.75	2.17	2.30	37.14
1900	0.76	4.52	2.05	2.08	6.67	2.54	4.04	2.46	4.64	1.78	2.29	0.96	34.79
1901	1.78	1.95	2.46	1.44	0.38	1.52	2.10	1.08	0.45	1.86	1.68	3.88	20.58
1902	1.03	0.96	3.95	2.[illegible]	1.41	8.48	1.30	3.58	3.74	1.91	2.43	4.48	35.94
1903	1.67	3.28	3.44	3.40	2.47	3.40	1.34	4.44	5.48	1.85	0.53	1.64	32.94
1904	3.50	0.43	6.17	5.16	3.33	5.99	5.34	4.58	4.18	1.35	0.32	1.84	42.19
1905	1.40	0.67	2.09	2.94	2.98	0.49	5.09	4.21	4.46	8.17	1.54	2.19	36.23
1906	1.86	3.17	4.08	2.34	4.44	5.10	1.60	4.26	5.32	1.41	3.92	3.40	40.90
1907	5.52	1.42	2.38	3.14	2.62	5.54	6.74	3.33	0.55	2.82	1.64	1.72	37.42
1908	2.04	3.86	2.78	6.75	4.20	2.86	5.46	0.72	1.74	0.54	2.08	1.44	34.47
1909	2.04	3.64	2.52	5.53	5.40	3.90	6.08	1.28	4.17	3.92	6.74	2.06	47.28
1910	3.48	3.88	0.42	2.92	5.26	3.34	6.60	3.08	7.27	4.29	0.68	1.70	42.92
1911	0.70	2.79	2.46	4.77	1.50	2.08	2.17	3.47	5.49	3.10	3.10	2.37	34.00
1912	1 48	3.39	5.74	7.66	4.75	4.18	3.17	3.52	3.10	1.95	2.70	0.42	42.06
1913	5.99	1.01	5.61	3.30	0.56	3.04	1.92	0.24	5.04	5.18	3.52	1.58	36.99
1914	2.43	3.10	0.93	3.58	0.48	0.65	2.92	3.31	2.91	3.78	1.78	....	.....
1915	....	1.98	0.66	1.67	8.05	6.00	4.28	8.32	8.03	0.69	2.77	3.05	.....
1916	8.31	1.35	2.10	2.12	5.22	2.81	0.08	8.36	4.59	2.46	2.65	1.06	41.11

GRIGGSVILLE, PIKE COUNTY, ILLINOIS

1882	1.32	1.00	3.50	4.00	6.50	7.37	3.00	2.37	1.62	4.12	2.62	1.62	39.04
1883	1.00	5.50	1.50	4.00	3.37	6.87	2.25	1.75	0.87	6.37	3.25	0.75	37.48
1884	1.25	2.37	....	2.50	4.37	5.25	2.37	3.12	3.24	4.25	1.87	2.50	.....
1885	2.12	0.87	0.62	6.00	2.62	4.50	0.87	2.62	5.75	2.75	1.50	1.75	31.97
1886	2.71	2.50	1.50	2.37	2.60	4.42	0.20	3.08	6.36	0.77	*2.10	0.66	29.27
1887	1.40	4.62	1.57	2.36	2.89	1.97	2.72	0.61	4.36	0.52	2.32	4.05	29.39
1888	3.11	2.40	3.84	1.25	7.83	9.77	6.81	2.86	4.00	1.88	4.30	2.47	50.52
1889	2.84	2.40	1.05	*2.30	9.33	4.98	2.87	0.76	4.56	4.47	1.12	2.02	38.70
1890	3.31	1.48	2.75	2.85	3.31	5.32	1.47	1.85	2.47	1.43	1.40	0.28	27.92
1891	0.87	3.52	2.25	3.61	2.42	1.76	0.98	1.75	1.53	2.11	4.15	0.87	25.82
1892	2.05	3.73	2.67	6.97	8.93	1.85	5.94	0.85	3.46	1.52	3.20	0.92	42.09
1893	0.42	2.82	6.22	7.69	5.65	3.80	3.38	0.35	1.37	0.33	1.25	1.38	34.66
1894	2.06	2.36	2.15	2.85	2.30	2.97	0.78	1.19	2.78	0.78	1.48	1.32	23.02
1895	1.36	0.22	3.15	2.35	2.46	3.94	6.25	2.68	3.51	0.85	2.95	6.21	35.88
1896	1.50	2.16	0.56	3.05	8.10	3.29	8.10	2.72	9.32	1.60	1.65	0.38	42.43
1897	6.74	1.39	4.20	4.25	2.91	5.45	4.50	2.16	0.46	0.25	3.38	2.34	38.17
1898	4.46	2.19	5.78	4.95	8.30	4.94	3.56	4.49	6.83	3.01	3.66	0.97	53.14
1899	0.42	1.54	3.81	1.80	13.10	1.97	3.16	4.43	3.79	3.33	2.16	1.27	40.78
1900	1.78	6.01	1.54	1.81	4.20	2.40	3.59	1.81	5.50	2.80	1.66	0.45	33.55
1901	2.06	1.51	3.25	1.46	0.46	3.55	2.74	0.22	3.65	1.80	0.77	2.82	24.29
1902	0.56	1.53	2.67	3.99	4.21	7.33	2.89	7.20	3.36	2.58	3.74	2.65	42.71
1903	1.30	2.62	3.20	4.59	3.34	3.14	2.10	4.52	4.89	2.53	0.68	1.05	33.96
1904	3.93	1.60	5.60	5.92	5.86	5.05	5.09	5.41	6.26	0.50	0.15	1.02	46.39
1905	1.60	1.50	1.45	2.85	2.67	1.60	2.95	4.67	5.25	4.27	1.95	1.69	32.45
1906	2.74	2.26	3.05	2.71	2.83	2.74	0.85	4.40	6.56	1.98	2.70	2.65	35.47
1907	5.38	0.49	3.27	3.25	3.35	5.00	5.82	6.97	2.24	1.70	1.80	0.52	39.79
1908	1.05	2.75	1.94	5.66	5.60	3.69	6.53	1.30	0.88	0.10	1.41	1.28	32.19
1909	1.81	2.25	1.53	4.47	7.50	3.27	4.11	0.33	4.64	4.36	3.30	1.21	38.78
1910	1.07	0.76	T	2.72	6.86	2.74	4.45	0.85	4.57	1.65	1.36	0.78	27.81
1911	1.47	1.97	1.97	4.57	1.21	1.19	2.92	3.68	13.77	3.00	2.15	1.47	39.37
1912	0.25	1.18	5.30	4.45	4.17	5.26	2.36	3.43	4.29	5.10	1.45	0.72	37.96
1913	2.26	2.19	4.65	3.56	1.22	4.54	0.64	0.35	3.10	3.87	*1.94	0.79	29.11
1914	1.64	2.24	1.03	2.10	0.37	0.85	1.66	3.38	7.56	3.65	0.36	2.06	26.90
1915	2.09	....	0.56	2.93	5.94	14.77	6.52	6.87	8.89	0.76	3.77	2.10	.....
1916	6.11	0.71	1.56	1.41	7.13	5.52	1.83	7.78	1.42	0.92	2.09	1.46	37.94

*Interpolated from surrounding stations.

HAVANA, MASON COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1870	....	....	....	....	....	....	....	....	3.86	3.95	2.50	1.71	.....
1871	4.28	1.60	4.25	2.05	1.00	3.05	5.25	2.15	....	3.05	1.95	2.45	.....
1872	0.50	1.60	2.43	2.03	2.18	9.83	4.78	1.13	4.35	0.84	2.02	1.61	33.30
1873	5.00	1.83	0.99	6.20	5.58	1.24	5.50	0.89	5.69	3.17	1.68	7.72	45.49
1874	2.61	1.87	1.22	2.96	2.42	2.71	2.33	6.48	2.42	1.27	3.20	0.93	30.42
1875	0.37	2.54	4.14	2.44	4.74	4.83	8.57	1.80	5.84	2.80	0.31	2.08	40.46
1876	0.82	1.41	7.03	2.69	4.35	5.60	9.61	3.06	7.00	1.55	2.20	0.20	45.52
1877	0.81	0.10	5.29	3.01	2.65	9.13	2.17	2.92	2.20	6.90	4.70	4.45	44.33
1878	1.28	3.56	2.95	....	....	....	....	....	....	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1892	1.65	1.98	1.54	4.84	7.69	3.02	2.29	....	3.01	0.98	3.25	1.42	.....
1893	0.79	3.49	2.94	7.95	5.48	2.00	4.25	0.73	2.34	0.22	0.76	2.06	33.01
1894	2.08	2.32	2.13	1.68	2.23	3.26	1.04	1.84	3.67	1.11	1.98	1.97	25.31
1895	1.36	0.32	1.04	2.68	1.51	1.91	4.89	4.53	4.34	0.41	3.80	6.03	32.82
1896	1.21	2.13	0.98	3.15	4.31	3.25	4.87	3.36	5.30	0.58	1.84	0.33	31.31
1897	6.66	1.32	4.53	3.74	1.08	3.58	5.22	1.22	0.51	0.08	3.41	1.82	33.17
1898	4.64	2.08	4.84	2.90	7.63	4.58	2.49	2.78	6.92	2.55	2.24	1.45	45.10
1899	0.77	2.21	3.39	1.26	7.31	2.24	7.11	3.26	4.18	3.34	2.41	2.73	40.21
1900	1.88	5.54	0.72	1.01	1.33	3.48	4.13	9.02	2.65	2.00	1.57	0.40	33.73
1901	2.54	1.09	7.30	0.89	0.66	5.02	1.85	1.04	1.61	0.66	0.50	0.73	23.89
1902	0.85	1.42	4.31	2.70	2.57	....	....	....	....	....	....	....	.....
1903	....	....	....	....	....	2.55	3.02	5.48	5.66	2.18	0.89	1.35	.....
1904	3.11	1.46	4.32	4.03	4.19	3.40	4.50	2.50	3.02	0.31	0.17	1.26	32.27
1905	1.60	2.20	1.69	3.91	2.69	2.71	2.58	4.42	4.69	2.91	2.54	1.72	33.66
1906	1.69	1.37	2.94	3.26	1.84	2.73	1.78	3.51	5.24	0.85	2.37	1.53	29.11
1907	6.79	0.22	2.54	3.11	2.54	3.89	6.23	6.73	1.53	0.59	1.59	2.41	38.17
1908	0.55	4.35	1.06	4.33	8.73	4.45	2.94	1.67	0.74	0.53	2.01	1.17	32.53
1909	1.55	3.85	1.80	5.39	4.64	5.68	4.84	1.95	5.68	3.13	3.61	2.13	44.25
1910	1.88	1.15	0.26	3.82	7.34	2.24	3.35	0.58	6.60	1.51	1.19	0.98	30.90
1911	2.06	2.31	2.11	3.47	1.51	2.99	1.91	1.86	13.14	2.07	2.01	2.06	37.50
1912	0.58	1.33	2.70	5.09	3.16	2.10	1.80	1.87	5.74	5.57	1.50	0.81	32.25
1913	1.21	1.74	1.53	3.24	1.90	3.15	1.46	1.52	1.59	2.27	2.99	0.70	23.30
1914	0.81	1.33	0.65	1.85	1.48	2.24	3.25	3.27	4.10	1.91	0.04	2.02	22.95
1915	2.28	1.79	0.73	1.68	6.34	3.64	3.43	8.33	6.06	0.53	3.47	1.52	39.80
1916	9.74	0.75	2.61	1.57	7.65	2.02	0.25	6.50	1.63	1.82	1.44	1.60	37.58

HILLSBORO, MONTGOMERY COUNTY, ILLINOIS

1895	....	....	....	....	1.72	2.47	6.81	3.24	2.83	0.68	3.28	5.44	.....
1896	0.73	2.43	1.23	1.98	6.62	3.14	4.15	2.08	4.80	1.74	2.58	0.77	32.25
1897	4.02	2.02	6.04	4.07	1.59	3.93	5.16	1.16	T	0.25	5.80	2.82	36.86
1898	5.51	3.07	7.78	3.80	7.45	3.39	5.33	2.69	5.56	5.18	2.32	2.00	54.08
1899	1.83	2.51	3.54	1.29	7.28	2.84	2.18	7.49	1.59	3.67	2.45	3.48	40.15
1900	0.52	4.60	1.70	1.31	5.14	6.10	2.96	0.42	3.27	3.02	2.78	0.95	32.76
1901	1.92	1.98	3.05	2.15	1.46	2.54	1.93	4.26	1.03	2.31	1.72	3.66	28.01
1902	0.82	0.89	4.95	2.79	3.31	8.93	1.39	5.71	5.32	2.52	3.34	4.00	43.97
1903	1.19	3.16	2.22	3.57	2.83	4.26	2.56	5.63	1.87	1.78	0.61	3.05	32.73
1904	3.15	0.90	6.53	5.05	4.14	4.54	5.38	4.41	5.44	0.62	0.09	1.01	41.26
1905	2.98	0.86	1.63	3.21	4.67	1.96	5.32	2.53	3.16	9.72	1.65	2.15	39.84
1906	3.56	2.42	4.47	2.08	3.15	4.85	0.50	2.37	5.83	1.65	4.25	2.02	37.15
1907	4.89	0.55	1.90	2.78	7.00	4.88	7.53	5.81	0.96	3.90	1.77	3.36	45.33
1908	2.09	4.76	2.10	5.03	8.28	4.53	2.52	0.78	1.54	0.10	1.85	1.62	35.20
1909	2.30	4.85	2.78	7.81	4.33	3.79	6.25	1.04	6.45	3.79	6.23	2.16	51.78
1910	2.26	2.76	T	5.19	6.03	3.57	4.20	5.19	6.14	5.00	1.05	1.45	42.84
1911	1.93	2.78	1.92	4.95	1.50	1.28	2.78	4.14	7.46	4.08	2.71	1.94	37.47
1912	1.01	1.16	5.24	7.64	3.24	3.03	3.67	2.00	1.51	1.75	1.85	0.50	32.60
1913	6.84	1.40	7.97	2.80	1.27	3.13	1.96	1.87	7.22	3.38	4.59	0.72	43.15
1914	1.64	3.59	0.50	2.97	0.13	1.07	2.93	4.46	2.31	3.25	1.11	1.63	25.59
1915	2.56	2.08	0.38	4.48	9.66	6.89	5.38	13.12	1.55	0.48	1.38	3.16	50.97
1916	7.98	0.93	1.07	1.36	2.60	5.29	0.73	6.58	2.47	2.22	1.93	1.93	35.09

HOOPESTON, VERMILION COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1902	....	....	....	....	....	14.37	4.85	2.30	3.01	1.99	2.88	2.60	.....
1903	1.94	3.03	0.64	6.45	3.77	1.84	3.85	5.78	1.64	1.92	1.80	2.45	35.11
1904	5.20	2.16	7.36	2.61	2.35	1.87	4.36	2.81	3.91	0.38	0.08	1.35	34.44
1905	1.76	2.77	1.24	3.91	4.53	2.15	3.81	3.75	5.09	2.82	2.83	1.47	36.13
1906	2.52	1.52	4.46	1.84	3.58	1.57	2.34	7.87	2.31	1.50	5.55	3.57	38.63
1907	5.89	0.22	4.26	2.90	3.28	5.34	6.48	2.08	5.09	0.94	2.27	3.88	42.63
1908	1.41	6.23	3.64	4.45	8.07	0.86	2.19	1.11	1.79	0.33	2.81	1.61	34.50
1909	2.87	6.83	1.76	6.45	4.24	4.18	6.07	5.28	2.38	2.10	3.47	3.61	49.24
1910	2.99	1.86	0.46	2.46	5.38	1.73	4.66	2.23	5.12	*1.45	0.85	2.07	31.26
1911	3.04	1.97	2.29	4.45	2.26	2.13	3.42	2.92	7.28	4.19	3.54	1.71	39.20
1912	1.71	2.11	3.25	5.77	3.88	3.56	6.62	5.50	2.13	1.80	2.97	0.70	40.00
1913	6.21	1.46	6.96	2.51	1.99	3.28	2.58	5.14	2.44	3.71	3.31	1.24	40.83
1914	2.18	2.61	2.02	2.69	4.29	1.80	1.52	2.27	1.63	3.24	0.62	2.56	27.43
1915	2.37	2.64	1.26	2.29	4.30	2.33	7.88	3.50	6.90	1.01	1.50	1.96	37.94
1916	6.55	0.50	1.86	1.51	5.97	5.29	2.43	2.50	1.83	3.33	2.08	2.88	36.73

*Interpolated from Rantoul.

KEOKUK, LEE COUNTY, IOWA

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1872	0.07	0.39	2.88	3.86	3.70	5.81	6.77	1.97	2.26	0.42	0.74	0.50	29.37
1873	3.40	0.53	0.51	5.65	3.42	1.21	7.73	0.54	3.37	4.69	1.43	8.56	41.04
1874	3.92	0.88	1.14	2.40	1.65	4.01	4.61	3.87	7.92	1.94	2.17	1.26	35.77
1875	0.61	1.84	1.67	0.89	6.70	•8.33	12.70	3.83	4.62	2.71	0.59	3.93	48.42
1876	3.68	1.45	3.45	3.99	5.28	6.73	6.79	4.03	11.08	2.12	2.82	0.23	51.65
1877	0.84	0.15	3.86	4.22	5.55	7.82	7.06	2.52	3.61	7.11	3.05	2.90	48.69
1878	0.17	2.95	3.78	2.31	3.47	3.93	2.37	5.27	1.36	2.31	1.93	1.95	31.80
1879	0.50	0.53	1.71	1.56	2.27	2.63	1.98	4.57	1.12	0.28	3.91	1.45	22.51
1880	3.91	1.94	1.83	4.79	5.92	3.06	2.25	3.81	3.21	2.02	1.13	0.67	34.54
1881	0.50	2.58	2.42	3.12	1.35	8.70	3.08	0.86	4.10	8.01	2.59	1.70	39.01
1882	1.07	1.54	3.30	3.22	7.11	9.45	4.53	3.09	1.52	2.71	2.25	1.75	41.54
1883	1.24	6.13	1.07	2.97	4.87	5.88	3.15	1.32	1.76	6.95	2.09	1.20	38.63
1884	0.85	1.88	3.37	1.31	3.16	4.03	2.30	2.74	4.25	3.35	1.73	3.91	32.88
1885	2.44	1.14	0.17	3.33	2.59	6.97	2.29	5.98	3.77	3.59	0.88	1.96	35.11
1886	2.08	1.40	2.25	1.52	4.49	2.86	0.65	5.90	3.95	2.38	1.15	1.03	29.66
1887	1.48	5.19	0.76	1.84	2.54	1.55	1.57	2.38	3.18	1.98	1.18	2.73	26.38
1888	1.57	2.17	3.45	1.85	5.06	5.42	6.00	2.07	2.13	1.63	2.83	1.61	35.79
1889	1.89	0.90	1.04	3.60	5.72	2.97	6.78	0.95	5.14	2.88	1.80	1.08	34.75
1890	1.81	1.09	2.43	1.79	3.34	3.41	2.49	1.77	4.46	2.44	1.87	0.08	26.98
1891	2.59	1.32	2.27	•5.06	2.56	3.66	2.77	6.10	0.49	1.49	3.60	1.33	33.24
1892	1.96	1.61	2.91	6.15	6.34	2.65	6.18	1.07	3.21	0.71	3.16	1.50	37.45
1893	0.92	1.76	2.66	5.41	4.36	2.37	2.60	1.16	3.18	0.33	2.29	0.90	27.94
1894	2.24	1.46	2.52	2.75	3.06	2.85	0.37	0.51	4.86	1.28	2.24	1.06	25.20
1895	1.44	0.19	1.05	3.38	3.15	2.61	5.46	2.68	2.67	0.37	2.58	4.24	29.82
1896	0.85	1.23	0.88	2.35	4.40	2.18	8.01	3.90	9.44	1.71	1.01	0.81	36.77
1897	4.90	0.96	4.16	3.54	1.86	5.43	6.75	0.65	0.64	0.24	2.17	1.84	33.14
1898	3.13	1.16	5.98	4.80	6.70	4.77	3.06	6.92	8.07	3.99	1.52	1.38	51.48
1899	0.49	1.65	2.66	3.28	11.47	2.78	5.39	4.01	4.32	2.06	1.19	1.67	40.97
1900	2.46	3.24	1.43	2.10	4.56	1.06	2.20	4.21	5.02	5.36	1.72	0.25	33.61
1901	1.41	0.75	2.59	2.29	1.95	6.34	2.02	0.15	2.14	0.93	0.80	1.17	22.54
1902	0.44	1.02	2.24	3.13	3.63	7.59	4.87	6.93	1.82	2.38	2.60	2.21	38.86
1903	0.77	1.42	3.03	4.91	3.56	1.40	1.27	4.80	7.16	3.23	0.87	0.86	33.28
1904	2.70	0.70	3.46	5.11	3.94	3.62	4.48	4.63	8.33	0.30	0.21	1.45	38.93
1905	0.60	1.37	1.78	3.32	3.01	6.57	2.89	3.16	4.15	3.41	2.32	1.03	33.61
1906	2.40	2.50	2.82	2.16	1.83	1.48	1.46	2.87	2.94	0.73	1.92	1.90	25.01
1907	5.07	0.10	5.05	2.02	3.44	6.40	6.26	5.50	1.94	0.47	1.17	1.38	38.80
1908	0.51	2.86	1.76	1.82	10.09	4.32	3.70	2.50	2.22	0.87	3.05	0.58	34.28
1909	1.26	2.44	1.84	4.99	3.03	5.11	5.46	0.68	3.46	4.48	3.97	2.56	39.28
1910	1.61	0.99	0.53	2.91	6.87	1.34	2.74	0.92	2.08	0.81	0.23	0.79	21.82
1911	2.66	2.35	1.79	4.13	0.42	0.65	6.48	1.74	7.67	2.19	2.88	1.87	34.83
1912	0.18	0.94	1.88	2.41	1.82	2.23	4.45	2.50	1.73	4.47	[illegible]	0.50	24.42
1913	1.04	2.39	2.82	2.62	3.87	4.15	0.09	1.63	1.42	1.43	[illegible]	1.35	25.03
1914	1.31	1.12	1.97	1.94	1.73	3.34	2.09	2.61	6.22	1.65	[illegible]	1.55	25.94
1915	0.90	1.43	0.90	1.27	5.79	9.99	6.34	1.43	6.16	•0.38	2.85	1.49	38.93
1916	5.18	0.59	1.37	2.44	6.63	3.74	0.10	4.71	3.41	2.75	1.75	0.73	33.40

LA HARPE, HANCOCK COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1856	....	....	0.25	3.13	8.61	1.10	5.99	1.53	1.26	4.52	4.97	6.06	.....
1857	0.39	4.80	2.56	0.89	2.03	3.70	1.45	4.10	2.72	2.32	2.43	1.36	28.75
1858	2.05	1.52	3.17	7.22	9.51	5.86	7.93	2.33	2.46	3.01	3.11	2.88	51.05
1859	3.83	3.68	4.39	3.35	7.81	6.78	1.22	5.43	3.72	1.80	1.79	1.08	44.88
1860	....	....	....	....	....	....	....	....	....	....	....	....	.....
1861	1.68	2.94	3.63	3.96	3.89	4.99	1.37	1.57	4.27	2.31	0.41	1.49	32.51
1862	4.68	0.64	1.80	6.68	1.44	6.85	....	....	7.61	1.46	2.09	6.32	.....
1863	2.80	....	2.21	....	2.81	0.27	2.62	2.46	3.43	3.08	0.61	5.99	.....
1864	1.58	0.58	2.26	6.76	2.16	1.42	5.26	1.29	4.16	2.90	3.88	3.55	35.80
1865	0.15	2.81	4.02	5.77	0.69	6.77	9.58	1.69	5.81	3.34	0.12	1.25	42.00
1866	3.52	1.42	1.77	4.78	2.12	1.74	3.19	3.28	10.30	3.83	0.51	2.88	39.34
1867	1.85	2.53	1.68	2.00	4.98	3.65	3.70	1.86	1.78	0.99	1.33	1.30	27.65
1868	0.92	0.79	5.62	5.36	7.03	2.05	5.42	4.36	4.29	1.75	5.01	2.57	45.17
1869	2.16	2.56	0.95	4.48	5.18	8.13	7.77	6.57	1.82	2.19	3.42	2.07	47.30
1870	2.11	0.12	5.61	0.63	1.73	2.35	2.01	5.41	5.78	5.19	1.39	1.40	33.73
1871	4.49	1.59	3.85	3.05	2.60	4.70	2.81	6.48	1.55	5.62	2.76	1.31	40.81
1872	0.20	0.85	3.06	2.93	3.33	4.96	6.27	2.72	2.56	0.99	1.04	1.41	30.32
1873	3.93	1.24	0.84	7.41	3.74	1.41	6.23	0.46	5.32	3.85	1.57	7.63	43.63
1874	2.88	1.12	1.57	....	2.00	6.61	3.42	4.95	2.18	0.98	2.22	1.07	.....
1875	0.32	2.00	2.83	1.76	6.09	5.59	14.04	1.30	6.64	2.35	0.52	3.89	47.33
1876	1.89	1.57	3.24	4.35	4.47	4.06	4.97	7.98	10.67	2.40	1.78	0.20	47.58
1877	0.82	0.14	4.62	2.58	3.96	6.96	6.24	3.08	3.27	9.27	2.89	4.00	47.83
1878	1.14	3.31	5.16	3.28	4.91	2.89	3.85	6.06	1.13	2.85	1.17	3.82	39.57
1879	0.73	0.79	1.91	1.26	1.63	3.02	3.15	5.20	2.06	0.19	3.97	1.51	25.42
1880	2.51	2.08	2.16	5.74	5.38	2.64	1.35	3.34	2.26	1.38	....	....	.....
1881	....	5.34	....	....	....	....	....	....	....	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1895	....	....	....	1.71	1.40	3.13	4.89	3.24	3.25	0.34	3.40	5.65	.....
1896	1.26	2.14	1.18	2.35	4.80	5.16	7.80	7.96	12.28	2.00	2.53	0.99	50.45
1897	10.38	1.83	6.22	5.85	2.41	5.80	3.87	1.86	1.39	0.26	1.26	2.10	43.23
1898	2.94	1.40	5.12	3.91	8.56	2.59	2.35	10.40	6.42	3.15	1.65	0.42	48.91
1899	0.35	1.38	3.14	3.17	12.57	2.60	2.58	4.32	2.82	1.97	1.52	1.17	37.59
1900	2.15	4.26	1.55	1.52	3.50	0.53	3.06	2.85	2.90	4.70	1.38	0.25	28.65
1901	1.17	1.65	2.24	1.30	2.10	5.10	5.15	0.50	2.07	0.85	1.08	0.69	23.90
1902	0.65	1.30	3.40	2.95	3.00	9.70	6.75	9.05	2.50	2.65	2.90	2.04	46.89
1903	2.07	2.13	1.92	5.30	3.00	2.20	1.45	5.00	7.65	4.05	1.02	0.88	36.67
1904	5.48	0.90	5.17	2.85	4.60	4.00	6.45	4.20	8.15	0.45	0.50	1.92	44.67
1905	1.13	1.99	1.25	4.47	4.55	12.60	2.40	5.55	1.65	2.80	2.10	1.14	41.63
1906	3.35	2.50	4.19	1.70	3.70	3.35	4.25	2.15	4.10	1.00	1.15	2.20	33.64
1907	7.62	0.30	6.40	2.60	2.75	4.45	6.70	5.10	1.95	0.30	0.90	1.26	40.33
1908	2.45	3.10	2.27	1.64	11.25	5.60	2.40	1.24	2.03	0.70	2.34	0.60	35.62
1909	1.35	3.32	2.09	3.52	4.87	7.15	6.18	3.31	4.68	3.52	3.61	2.92	46.52
1910	0.62	0.60	0.34	2.37	6.88	1.99	3.61	0.38	2.74	0.75	0.11	0.82	21.21
1911	4.17	1.87	1.90	2.94	1.53	1.68	7.17	1.44	11.84	2.06	1.88	2.07	40.55
1912	0.52	0.90	1.14	2.20	2.71	2.17	4.36	2.55	1.70	3.97	2.06	0.57	24.85
1913	1.14	2.26	2.74	2.82	3.53	3.54	0.23	1.39	1.96	2.07	2.43	0.94	25.05
1914	0.91	0.56	1.92	2.08	2.27	1.59	0.56	4.25	7.25	1.69	0.29	1.97	25.34
1915	2.18	2.35	0.47	0.89	5.34	5.33	9.83	1.50	5.18	0.58	2.72	1.56	37.98
1916	5.20	0.38	2.75	2.59	7.98	4.66	0.10	3.06	3.60	2.58	1.84	0.84	35.58

Values for 1856 to 1881, inclusive, are for Augusta. All other values are for La Harpe. The stations are 24 miles apart.

LINCOLN, LOGAN COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1888	1.40	1.45	3.41	1.51	8.16	2.46	3.75	2.85	1.60	2.51	2.61	2.37	34.08
1889	1.72	1.88	1.61	0.95	4.19	7.07	4.71	0.30	4.81	1.70	4.10	1.50	34.54
1890	4.35	1.36	1.99	2.71	2.56	3.70	2.50	2.90	0.80	2.90	1.10	0.20	27.07
1891	1.69	4.51	3.20	3.46	1.05	3.36	3.25	6.06	0.15	0.78	4.52	1.48	33.41
1892	1.45	1.86	1.58	....	....	5.98	....	....	....	....	....	....	.....
1893	....	....	....	....	....	3.41	2.05	0.85	2.25	1.11	1.64	1.30	.....
1894	2.79	2.62	3.23	2.60	2.88	1.91	3.27	1.51	4.06	0.81	1.50	2.48	29.61
1895	1.25	1.14	2.01	1.60	1.32	2.84	4.30	1.47	3.75	0.31	2.67	7.42	30.08
1896	1.32	2.22	1.14	2.31	2.89	4.74	8.14	1.95	5.06	0.48	1.95	0.51	32.66
1897	5.19	1.50	3.82	2.98	1.47	4.17	3.10	1.42	1.21	0.37	3.84	2.35	31.42
1898	4.78	2.20	9.90	2.47	5.04	3.71	0.56	2.77	5.14	4.79	2.26	1.50	45.12
1899	1.21	2.13	2.86	0.72	9.83	1.49	2.30	3.35	2.11	3.04	1.97	1.93	32.94
1900	0.31	5.27	1.22	1.19	2.66	3.96	5.76	6.88	4.24	2.96	4.04	0.68	39.17
1901	1.96	1.36	3.68	1.36	2.24	7.76	1.67	1.17	2.60	1.98	1.07	2.47	29.32
1902	0.67	1.40	4.15	3.34	1.38	8.46	3.34	5.64	4.13	2.24	2.62	2.21	39.58
1903	1.18	3.06	1.42	5.10	4.09	1.98	2.24	3.13	3.07	3.67	1.19	1.70	31.83
1904	2.74	1.00	5.53	5.61	2.81	3.44	2.22	4.32	8.78	0.50	0.02	1.08	37.95
1905	2.06	1.37	1.53	3.99	3.23	2.11	3.64	1.41	3.33	2.80	1.84	1.74	28.55
1906	....	2.10	2.90	2.45	2 30	2.12	0.61	2.72	3.72	1.11	3.58	3.26	.....
1907	5.99	0.24	....	2.52	5.54	3.30	3.57	3.50	2.63	1.28	2.01	3.82	.....
1908	1.37	4.33	....	4.95	8.77	1.64	1.96	2.77	....	0.49	1.44	1.69	.....
1909	2.29	1.84	1.55	5.04	....	....	....	....	....	3.10	4.22	2.86	.....
1910	2.71	1.08	0.47	3.56	5.97	1.38	2.99	0.79	4.41	1.40	1.12	1.18	27.01
1911	2.45	1.91	2.32	3.76	1.79	2.43	1.57	2.97	14.31	2.49	1.59	2.81	39.90
1912	0.91	1.60	3.77	5.07	4.28	2.45	2.72	4.33	1.52	3.99	2.34	0.68	33.61
1913	3.63	1.21	6.15	3.24	2.15	2.31	1.01	3.19	2.58	4.21	3.44	0.83	33.95
1914	1.73	2.99	0.80	2.67	6.03	2.82	1.80	2.49	1.98	1.78	0.22	2.38	27.69
1915	1.97	2.34	0.98	2.10	7.32	2.34	8.74	3.83	7.10	1.41	1.11	2.70	41.94
1916	5.57	0.75	1.35	1.51	6.23	2.91	1.39	2.51	2.51	3.32	2.41	1.19	31.65

Values for 1888 to 1892, inclusive, are for Beason, 8 miles from Lincoln.
Values for 1893 to 1905, inclusive, are for Mt. Pulaski, 10 miles from Lincoln.
Values for 1906 to 1908, inclusive, are for Lincoln.

MANCHESTER, SCOTT COUNTY, ILLINOIS

1855	13.53	1.56	2.91	3.97	6.43	2.00	3.52	2.06	2.76	2.55	2.82	3.92	48.03
1856	1.10	4.69	1.55	1.23	4.32	1.94	2.11	2.11	1.11	2.46	3.43	4.98	31.03
1857	0.85	6.91	2.62	0.77	2.73	3.84	2.28	4.52	2.39	1.67	3.33	1.85	33.76
1858	2.35	1.67	2.05	3.65	9.20	7.60	6.52	3.18	4.59	4.29	2.86	2.45	50.41
1859	2.06	2.48	4.15	3.62	10.76	5.50	2.70	2.81	2.84	1.22	2.92	1.30	42.36
1860	....	....	....	....	....	....	....	....	....	....	....	....	.....
1861	1.33	2.29	6.19	2.18	3.37	4.52	1.59	1.52	2.83	2.27	0.94	1.00	30.03
1862	5.15	0.72	2.66	7.05	2.56	2.32	5.34	1.70	4.69	1.77	2.30	3.54	39.80
1863	2.89	4.01	3.77	....	1.80	0.89	3.73	1.97	2.79	3.93	1.77	3.36	.....
1864	3.12	0.87	2.05	4.34	2.01	1.12	2.02	1.87	2.42	1.95	3.67	1.94	27.38
1865	0.34	5.23	4.58	....	....	....	....	....	....	....	....	1.68	.....
1866	3.74	4.03	3.11	4.16	4.95	1.22	4.01	2.89	7.08	5.98	0.50	2.03	43.70
1867	1.60	6.34	1.95	0.47	5.45	3.36	2.83	2.50	0.50	1.42	1.60	1.01	29.03
1868	1.19	0.19	6.81	5.60	5.59	3.22	1.70	3.02	3.89	1.43	3.12	2.25	38.01
1869	3.67	1.97	2.43	6.25	4.38	4.82	6.98	1.86	0.94	1.67	2.89	2.87	40.73
1870	1.16	0.35	4.61	1.95	1.59	2.60	4.55	5.22	2.61	2.43	1.65	2.30	31.02
1871	3.50	1.55	4.40	0.95	2.48	1 95	1.40	0.80	0.08	3.10	3.05	2.70	25.96
1872	0.68	2.95	3.60	2.30	1.93	9.93	6.00	3.64	2.83	0.00	1.07	1.55	36.48
1873	5.01	2.50	1.80	5.25	7.26	3.05	2.85	1.88	2.89	2 83	3.15	....	.....
1874	2.36	3.19	2.75	3.30	2.75	1.90	3.00	5.60	3.15	....	....	....	.....

MARTINSVILLE, CLARKE COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1887	1.85	5.20	4.45	3.16	5.65	1.39	2.54	3.59	2.35	1.02	5.25	3.00	39.45
1888	....	1.25	2.22	2.75	....	5.26	....	6.71	1.36	1.18	7.80	....	.....
1889	1.01	1.08	0.99	0.27	4.20	7.65	3.00	1.30	5.00	3.34	4.67	0.91	33.42
1890	6.19	5.98	3.34	3.46	3.57	3.68	3.00	4.24	4.60	1.45	2.25	1.34	43.10
1891	2.23	4.67	3.93	1.35	0.72	1.55	0.79	6.55	1.12	1.09	3.61	0.99	28.60
1892	1.60	1.80	....	7.84	6.83	2.65	2.62	3.27	0.77	0.83	3.20	1.12	.....
1893	1.25	4.42	3.99	9.16	4.76	3.15	0.85	0.54	4.18	1.30	3.14	2.11	38.85
1894	2.43	2.83	2.20	3.72	4.37	1.10	3.44	3.45	1.70	1.20	0.98	3.49	30.91
1895	2.56	0.95	1.20	3.43	1.10	1.54	4.71	3.83	2.48	0.95	4.75	4.30	31.80
1896	0.85	1.80	1.90	1.92	3.37	3.23	10.57	2.83	4.30	0.95	3.27	1.41	36.40
1897	4.15	2.50	7.27	5.72	3.47	6.77	2.30	0.25	0.47	0.69	6.01	2.83	42.43
1898	3.86	1.26	9.64	2.48	2.79	4.20	1.15	3.44	4.90	4.35	2.29	0.85	41.21
1899	1.80	1.38	4.05	1.20	5.20	2.25	4.51	2.70	0.69	2.79	1.79	2.55	30.91
1900	0.23	*2.66	*1.56	*0.75	*4.58	*5.07	*5.53	*3.37	*4.23	*2.15	*2.96	*0.72	33.81
1901	*0.57	*0.80	*1.28	....	....	†6.41	†0.43	†1.56	†0.42	†2.40	†1.10	†3.93	.....
1902	....	....	†1.97	2.49	2.87	6.48	4.28	4.57	3.78	1.39	....	....	.....
1903	....	....	....	3.81	0.85	2.54	3.06	4.50	2.93	2.28	1.55	....	.....
1904	3.57	0.55	7.97	0.95	3.55	4.61	3.20	2.25	5.01	0.60	0.25	....	.....
1905	1.81	....	1.52	4.01	5.41	1.55	5.64	....	2.00	4.99	2.70	1.75	.....
1906	3.85	1.55	3.55	2.40	1.65	5.07	2.74	5.43	3.65	0.80	4.65	4.70	40.04
1907	7.57	0.09	1.90	2.45	5.08	4.86	4.98	3.85	0.40	2.65	3.40	2.20	39.43
1908	0.20	3.25	3.90	3.60	11.35	3.17	2.67	1.14	1.87	0.21	3.72	1.23	36.31
1909	2.76	3.10	1.65	6.47	6.99	6.61	9.43	1.03	2.88	3.19	4.65	3.03	51.79
1910	1.33	2.20	0.40	2.42	4.63	2.15	7.74	2.89	2.30	6.10	3.10	1.15	36.41

*At Weir, 7 miles distant. †At Melrose, 10 miles distant.

MORRISONVILLE, CHRISTIAN COUNTY, ILLINOIS

1895	....	....	....	....	....	....	....	1.50	3.25	0.25	3.28	4.68	.....
1896	0.43	1.41	1.25	1.98	5.04	3.65	5.98	3.07	4.44	1.19	2.59	0.44	31.47
1897	3.35	1.20	6.02	5.27	4.09	4.99	3.60	1.36	0.29	0.12	5.29	2.78	38.36
1898	5.02	2.74	6.72	2.92	9.14	2.74	2.74	3.38	4.60	5.11	3.09	2.02	50.22
1899	1.94	2.42	2.96	2.25	5.66	1.84	0.72	3.84	0.98	3.75	2.11	2.23	30.70
1900	0.43	6.39	1.59	1.16	2.95	....	4.35	1.95	4.22	3.11	2.21	1.06	.....
1901	1.52	1.66	2.26	2.57	1.98	5.53	0.71	1.13	1.50	3.27	1.78	3.97	27.88
1902	1.00	0.93	4.20	2.81	1.02	10.61	1.30	4.43	2.89	2.45	2.93	3.02	37.59
1903	1.47	3.25	2.35	2.72	1.70	3.15	4.59	4.36	3.25	1.73	0.55	1.82	30.94
1904	2.33	1.14	8.67	5.10	2.89	4.05	6.78	3.19	4.62	0.74	0.07	1.20	40.78
1905	2.26	0.99	1.81	3.87	3.17	1.91	6.10	1.78	2.56	5.53	1.74	2.31	34.03
1906	3.44	2.60	3.65	2.41	2.77	1.45	1.87	3.34	2.90	1.17	3.92	2.47	31.99
1907	5.68	0.19	2.03	2.60	3.28	4.37	6.88	5.12	1.02	1.62	2.08	2.63	37.50
1908	1.33	3.48	2.14	5.57	7.49	2.15	2.21	2.71	1.49	0.11	2.91	1.48	33.07
1909	1.66	3.79	1.55	5.88	5.52	2.48	6.77	0.40	3.39	3.37	2.74	1.47	39.02
1910	1.77	1.42	0.04	3.43	8.65	3.77	5.05	2.19	4.78	2.44	1.66	1.49	36.69
1911	2.49	1.54	1.57	5.79	0.67	3.18	1.59	5.77	3.99	2.32	2.74	1.89	33.54
1912	0.74	0.97	4.62	5.70	3.64	1.78	2.00	2.56	1.18	1.88	1.73	0.51	27.31
1913	4.84	1.34	6.07	3.55	1.02	1.97	3.60	1.38	3.66	4.00	4.21	0.62	36.26
1914	2.05	2.25	0.62	2.44	0.31	1.37	1.85	2.81	2.83	1.84	1.11	1.62	21.10
1915	1.83	2.16	0.70	1.33	8.76	7.48	4.14	10.09	2.05	0.81	1.18	3.84	44.37
1916	7.42	1.15	1.26	....	3.38	7.86	1.24	2.45	2.36	2.05	1.95	1.48	.....

PANA, CHRISTIAN COUNTY, ILLINOIS

1882	....	....	....	....	....	....	....	3.68	0.15	2.00	2.75	1.50	.....
1883	1.28	4.50	1.00	2.00	4.31	3.15	5.75	1.50	0.75	8.00	3.72	0.82	36.78
1884	1.06	4.00	1.50	2.58	2.25	3.49	4.00	1.25	7.33	2.50	2.00	4.88	36.84
1885	2.60	0.88	0.18	5.11	5.41	10.50	6.61	3.59	7.00	5.33	1.33	1.65	50.19
1886	1.68	2.35	2.28	3.07	5.50	5.58	1.50	7.16	8.74	0.16	3.39	1.67	43.08
1887	0.65	6.08	3.41	5.68	6.50	1.66	3.05	5.35	5.08	1.33	7.58	6.41	52.78
1888	3.08	3.74	6.08	3.50	6.08	8.74	5.73	6.66	1.66	5.88	6.25	5.58	62.98
1889	2.73	2.05	3.25	1.25	6.83	4.68	2.24	0.08	4.57	2.75	8.16	4.33	42.92
1890	11.65	2.01	6.08	3.04	3.57	5.25	3.33	3.66	4.66	1.16	3.50	1.12	49.03

PANA, CHRISTIAN COUNTY—*Concluded*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1891	0.56	2.64	4.32	4.16	0.66	6.25	†2.10	6.50	1.00	2.26	10.09	1.79	42.33
1892	2.11	5.61	3.32	11.99	8.57	2.76	6.49	6.07	3.25	1.57	7.25	4.33	63.32
1893	0.48	4.60	3.77	....	1.60	2.99	2.49	0.30	2.74	0.28	....	....	.....
1894	....	....	....	....	....	....	....	....	....	....	....	....	.....
1895	....	....	....	....	....	....	....	1.50	3.25	0.25	3.28	4.68	.....
1896	0.43	1.41	1.25	1.98	5.04	3.65	5.98	3.07	4.44	1.19	2.59	0.44	31.47
1897	3.85	1.20	6.02	5.27	4.09	4.99	3.60	1.86	0.29	0.12	5.29	2.78	38.36
1898	5.02	2.74	6.72	2.92	6.49	2.31	2.84	3.17	3.90	4.85	2.48	1.38	44.27
1899	2.00	1.91	3.44	1.38	6.84	4.01	1.44	2.44	1.35	3.97	1.72	3.00	33.50
1900	0.51	5.31	1.66	1.32	2.30	6.17	5.49	1.98	3.36	2.00	3.63	1.21	34.94
1901	1.64	1.92	3.71	2.19	3.61	3.94	1.08	2.66	1.73	2.64	1.70	3.16	29.98
1902	1.47	0.96	3.83	2.94	1.71	10.43	1.48	5.51	4.01	2.32	3.16	3.68	41.50
1903	1.43	4.15	2.84	3.66	1.95	3.25	3.53	4.83	2.41	2.24	0.42	1.99	32.70
1904	2.85	1.19	7.86	4.48	2.00	3.50	6.39	4.20	4.26	0.54	0.10	1.34	38.71
1905	2.16	1.17	1.49	2.81	3.65	2.29	6.88	1.66	2.32	5.45	1.95	2.27	33.60
1906	2.78	2.38	4.75	3.94	2.46	3.87	0.89	3.18	7.18	1.03	4.86	2.99	40.26
1907	6.18	0.66	2.61	3.02	3.78	4.85	5.93	5.91	1.01	1.95	1.95	3.97	41.82
1908	1.97	5.87	2.37	5.42	10.21	2.38	2.48	1.60	1.05	0.18	3.09	1.55	38.12
1909	2.72	5.05	1.68	6.25	3.96	3.71	8.82	1.74	3.73	3.20	4.48	2.53	47.87
1910	1.90	2.33	0.40	3.49	6.06	2.52	4.30	6.71	5.95	2.11	1.96	1.05	38.78
1911	2.93	2.87	1.91	5.14	1.12	4.63	1.55	4.65	10.87	2.61	2.59	2.03	42.90
1912	1.24	1.87	4.78	5.10	3.65	3.14	3.69	3.39	0.80	2.84	1.85	0.99	33.34
1913	†5.45	1.46	6.46	†3.15	0.79	1.94	1.48	†2.06	†4.55	4.19	4.40	0.42	36.35
1914	2.15	*2.25	0.63	2.14	0.70	1.21	2.34	2.37	3.78	2.46	1.16	2.02	23.16
1915	2.83	2.53	0.77	3.01	8.20	6.80	4.58	11.23	2.12	0.66	1.15	3.90	47.28
1916	3.36	1.12	1.22	1.44	3.14	6.47	1.58	1.62	2.13	2.66	2.13	2.59	34.46

From August, 1895, to April, 1898, values are for Morrisonville, 19 miles distant.
†Interpolated from surrounding stations.
*Interpolated from Morrisonville.

PARIS, EDGAR COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1887	1.40	4.19	2.40	2.78	5.03	0.34	0.81	3.40	3.74	0.72	6.47	4.39	35.67
1888	2.75	2.10	3.52	2.52	4.35	4.62	2.94	4.09	2.44	2.66	4.78	2.82	39.09
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1892	....	1.31	0.09	7.50	10.70	4.50	3.50	....	....	....	....	....	.....
1893	....	....	....	6.26	4.70	4.24	1.19	0.38	3.24	1.41	3.10	1.69	.....
1894	2.95	2.64	3.80	2.17	3.31	1.78	1.74	2.00	3.78	0.69	3.45	1.51	29.82
1895	1.71	1.12	0.91	3.87	0.88	2.21	2.95	1.65	2.46	0.28	4.84	3.05	25.93
1896	....	....	....	1.28	5.92	5.45	3.39	5.41	5.94	....	1.96	....	.....
1897	....	....	2.99	4.63	2.04	5.60	2.70	0.58	0.38	0.25	6.41	2.98	.....
1898	4.29	1.69	3.34	2.41	3.05	3.84	1.67	3.31	4.71	3.78	2.30	1.37	40.71
1899	2.97	2.22	2.73	0.90	4.90	2.04	3.99	3.09	0.92	†3.92	3.59	2.33	34.10
1900	0.80	†5.31	1.63	2.05	2.17	6.37	4.35	4.75	3.13	4.04	3.64	0.98	39.22
1901	1.48	1.65	3.87	2.82	2.78	7.43	2.07	2.53	1.56	3.61	2.19	3.54	35.53
1902	0.87	1.20	2.93	1.56	4.97	9.04	4.26	4.71	3.31	2.11	4.22	3.89	43.07
1903	1.10	2.45	2.73	4.54	1.21	1.10	3.43	3.48	0.71	2.24	0.56	0.29	23.84
1904	1.25	....	....	2.97	3.58	2.32	1.57	3.20	4.64	1.01	0.30	2.26	.....
1905	1.26	2.03	1.98	3.75	4.91	0.45	5.31	3.43	4.36	3.73	2.39	2.42	36.02
1906	4.99	0.65	5.30	1.57	1.03	2.54	2.95	3.27	3.93	0.42	3.30	3.29	33.74
1907	5.26	0.07	3.05	2.50	2.53	....	....	....	0.70	2.79	3.47	3.10	.....
1908	1.53	5.11	4.64	5.57	9.27	2.48	2.75	0.80	1.79	0.20	3.05	1.12	38.31
1909	2.76	5.18	2.40	6.67	3.78	4.66	4.96	1.18	3.14	3.25	3.24	2.92	44.14
1910	2.60	2.82	0.23	3.59	4.13	3.00	5.30	1.63	4.66	3.90	2.65	1.25	35.76
1911	3.50	2.16	2.41	5.74	1.45	3.93	1.79	2.28	11.43	2.57	3.00	1.90	42.16
1912	1.09	1.22	4.24	5.19	4.59	2.46	8.56	5.81	2.65	1.01	2.15	0.65	39.62
1913	7.42	1.39	7.09	2.46	2.31	0.95	2.92	2.06	3.62	4.83	4.03	1.49	40.07
1914	1.23	2.67	1.85	2.61	1.40	2.18	3.11	3.59	2.73	3.10	1.74	1.82	28.03
1915	1.51	1.12	0.78	1.13	6.38	1.75	6.89	6.62	4.71	1.87	2.84	1.66	37.26
1916	6.58	0.63	2.54	1.15	5.19	7.21	3.04	2.18	1.72	1.86	1.77	3.52	36.89

†Interpolated.

PHILO, CHAMPAIGN COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1885	....	....	....	....	3.57	5.12	3.84	2.12	4.32	4.41	....	....	.....
1886	2.28	0.71	3.90	2.55	3.36	5.33	3.25	3.36	7.75	0.40	2.80	1.58	37.27
1887	0.81	2.94	2.62	3.37	5.00	1.50	0.98	2.77	4.26	0.81	2.96	4.05	32.07
1888	2.67	2.05	2.77	2.62	6.68	5.11	8.86	0.35	1.18	4.50	4.41	2.12	43.32
1889	1.23	2.19	1.36	1.04	5.88	11.16	4.47	0.84	2.64	3.21	3.48	2.04	39.54
1890	6.35	3.47	2.35	3.95	3.84	5.14	2.02	1.81	1.50	2.22	2.36	0.13	35.14
1891	0.89	2.10	4.32	2.46	1.14	3.15	1.52	4.21	0.59	0.82	6.14	1.55	28.89
1892	1.69	3.71	2.21	7.79	7.43	2.81	3.10	4.29	1.16	0.50	4.92	1.80	41.41
1893	1.02	4.51	3.87	8.28	6.38	1.67	0.66	0.46	3.65	0.65	3.48	1.28	35.91
1894	2.38	3.28	3.04	3.63	2.20	4.44	2.53	1.22	5.02	0.76	2.13	2.19	32.82
1895	1.08	1.28	1.08	2.38	0.82	2.73	3.01	1.28	3.72	0.85	3.24	4.99	26.46
1896	1.06	1.57	0.77	1.38	3.99	3.45	7.27	6.41	5.02	0.20	3.41	0.88	35.86
1897	4.25	1.56	3.68	3.48	1.97	6.22	3.48	1.20	0.45	0.54	5.08	2.65	34.56
1898	3.62	1.28	8.71	2.84	4.93	3.78	1.98	2.29	5.28	5.55	3.20	2.23	45.64
1899	2.50	2.31	2.31	0.87	4.44	2.60	1.82	2.93	0.50	4.22	2.16	2.56	29.22
1900	0.16	4.13	1.89	0.82	6.19	4.55	6.35	6.88	1.64	2.26	3.56	1.34	39.77
1901	2.01	1.99	3.11	1.80	2.66	5.72	3.73	2.44	1.19	3.57	1.36	3.75	33.33
1902	1.02	1.56	3.18	1.47	2.23	7.33	5.59	5.39	4.06	3.39	3.28	3.12	41.62
1903	1.45	3.16	1.45	5.50	2.32	3.36	3.49	2.39	1.77	2.87	2.04	2.20	32.00
1904	3.17	1.25	6.57	4.06	3.05	2.71	2.17	5.65	3.17	0.53	0.35	0.76	33.44
1905	2.18	1.68	1.10	3.79	4.62	3.54	6.00	1.31	4.79	3.11	1.01	1.87	35.00
1906	2.55	1.86	4.38	1.65	4.37	2.48	4.87	2.20	3.80	1.74	4.75	3.98	38.58
1907	7.60	0.16	4.22	2.42	3.48	5.98	6.08	4.03	0.58	2.13	2.27	3.46	42.41
1908	1.79	4.25	3.37	4.17	7.65	1.79	2.64	2.42	1.59	0.35	3.27	1.32	34.61
1909	2.54	5.11	1.23	7.73	2.83	3.80	8.16	2.88	2.68	3.21	2.96	2.37	45.50
1910	2.26	1.84	0.23	2.80	5.41	2.05	3.75	2.18	4.65	2.63	2.69	1.60	32.09
1911	2.24	1.76	2.09	4.11	0.84	2.41	2.73	2.63	8.92	3.95	2.82	1.56	36.06
1912	1.35	2.20	1.58	5.22	4.89	2.67	3.24	3.52	1.26	1.90	1.74	0.93	30.50
1913	6.69	1.03	6.09	2.35	0.57	1.64	0.38	1.59	4.46	3.34	4.08	0.45	32.67
1914	1.62	2.47	1.37	2.38	2.72	4.36	1.95	2.15	1.76	2.90	1.41	2.01	27.10
1915	1.96	2.62	1.05	1.75	5.55	3.38	8.38	5.89	....	....	....	....	.....

RANTOUL, CHAMPAIGN COUNTY, ILLINOIS

1891	....	....	....	....	....	....	....	....	....	....	5.01	1.19	.....
1892	0.96	2.41	2.28	6.04	8.17	4.38	3.51	1.56	0.93	0.62	4.56	1.39	36.81
1893	1.60	3.57	2.60	7.23	3.89	1.11	0.38	0.20	4.38	0.76	2.19	2.25	30.16
1894	1.91	1.77	2.75	3.58	4.39	2.37	0.41	2.45	5.21	0.39	1.58	1.16	27.97
1895	1.34	0.65	0.95	2.55	1.41	3.40	7.47	1.39	5.42	0.47	3.25	6.82	35.12
1896	0.86	1.38	0.87	1.68	4.95	4.08	6.86	3.33	5.73	0.22	2.25	0.80	33.01
1897	3.83	1.18	3.41	3.54	2.28	6.73	5.39	0.58	0.68	0.58	3.80	2.82	34.82
1898	3.46	1.76	7.20	2.04	5.94	4.99	1.87	3.87	3.86	4.58	3.28	1.98	44.83
1899	2.23	1.66	3.49	0.88	5.81	1.81	3.10	2.61	2.59	4.50	1.65	1.58	31.91
1900	0.18	2.48	2.72	0.92	4.69	7.31	5.96	5.91	5.53	2.32	2.82	0.93	41.77
1901	1.57	1.54	3.98	1.42	4.38	4.83	0.51	4.37	2.71	3.32	1.63	3.49	33.75
1902	0.77	1.90	3.09	2.72	3.29	13.54	5.69	6.09	4.73	2.85	2.37	2.96	50.00
1903	1.14	3.23	1.40	6.26	3.77	6.13	2.73	4.66	1.25	1.85	1.34	2.62	36.38
1904	3.95	1.38	6.78	4.62	3.29	1.11	6.60	3.16	3.39	0.76	0.10	1.25	36.39
1905	1.85	1.50	1.31	3.70	4.01	2.68	4.73	2.60	3.75	3.34	2.62	1.58	33.67
1906	3.47	1.50	4.09	2.23	2.51	2.30	3.49	5.75	4.74	2.00	4.91	3.08	40.07
1907	5.69	0.08	3.54	2.19	3.08	5.45	6.17	6.21	2.26	1.39	2.17	2.71	40.94
1908	1.49	4.66	3.00	4.83	10.66	1.71	2.17	1.89	1.43	0.38	2.70	1.66	36.58
1909	2.18	5.34	1.57	7.64	3.75	3.77	3.27	1.81	2.36	2.40	3.51	2.36	39.96
1910	2.50	1.54	0.43	2.72	6.56	2.08	2.58	2.13	4.57	1.45	0.80	1.57	28.93
1911	2.73	1.56	2.13	4.53	1.91	1.92	2.26	5.19	7.91	3.11	3.24	1.73	38.27
1912	1.50	1.12	3.04	5.91	3.43	2.47	5.40	4.37	1.41	2.81	2.78	0.75	34.99
1913	5.48	1.10	6.99	....	....	....	....	....	....	....	....	....	.....

RUSHVILLE, SCHUYLER COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1889	1.70	1.86	0.81	....	....	....	....	....	....	....	3.79	1.20	.....
1890	2.99	1.43	2.49	2.33	3.42	3.92	4.19	2.14	3.64	1.49	2.06	0.25	30.35
1891	1.05	2.09	3.49	4.49	4.74	2.57	4.78	7.94	0.61	2.34	4.93	2.13	41.16
1892	2.07	2.90	2.49	7.68	7.58	2.60	5.95	0.60	3.18	1.27	1.53	2.09	39.94
1893	1.16	3.02	3.77	9.10	7.36	3.03	2.45	1.91	2.96	0.22	1.72	0.81	37.51
1894	2.70	2.40	2.41	3.11	2.47	4.21	0.67	2.06	8.32	1.12	2.92	1.70	34.09
1895	1.75	0.87	1.03	2.38	3.32	3.88	5.53	4.85	3.44	0.53	4.72	5.90	38.20
1896	1.56	1.72	0.78	4.45	4.31	3.72	9.61	1.77	5.85	1.59	1.35	0.67	37.38
1897	6.03	....	....	....	....	....	....	....	....	....	....	....	.....
1898	....	....	....	....	....	....	....	....	6.68	2.22	2.47	0.97	.....
1899	0.89	1.99	2.75	1.14	8.33	2.58	4.25	3.00	4.26	3.48	1.96	2.02	36.65
1900	2.10	5.42	0.96	1.09	2.72	1.30	1.82	3.89	3.53	3.76	1.48	0.39	28.46
1901	2.50	1.21	3.37	1.89	0.69	3.86	2.65	0.70	2.63	0.71	1.07	1.75	23.03
1902	0.67	1.47	4.67	2.76	2.72	8.34	4.38	6.45	4.32	2.86	2.00	2.67	43.31
1903	1.03	1.50	2.45	5.63	4.41	2.26	3.18	4.26	3.99	1.98	0.97	0.95	32.61
1904	3.07	0.69	5.05	6.60	4.63	4.11	4.39	3.25	3.87	0.22	0.03	2.09	38.00
1905	0.51	1.07	1.75	3.53	3.23	5.33	2.83	3.02	5.39	3.11	1.03	1.72	32.52
1906	1.75	1.90	3.49	3.30	1.73	3.84	2.52	3.83	4.82	0.52	2.24	2.50	32.44
1907	5.86	0.25	2.83	3.99	3.66	4.26	6.82	5.94	0.89	0.84	1.30	2.00	38.64
1908	1.30	3.60	0.73	4.51	7.07	4.88	3.81	2.64	1.29	0.40	3.05	0.95	34.23
1909	2.02	2.70	1.02	5.16	5.56	3.51	3.99	0.81	3.99	2.92	2.57	2.32	36.57
1910	1.61	0.71	0.12	2.82	6.11	0.61	2.86	2.04	4.21	1.19	0.59	1.16	24.03
1911	2.45	1.62	2.33	3.66	1.77	2.82	3.07	1.91	14.65	2.18	2.12	2.39	40.97
1912	0.30	0.84	2.61	4.92	3.41	1.79	1.51	2.04	4.09	3.28	2.12	0.91	27.82
1913	0.94	1.40	3.88	3.05	1.77	1.95	0.58	0.44	2.22	2.87	3.35	1.09	23.54
1914	1.03	1.97	2.59	1.78	1.18	2.97	0.94	2.43	4.82	2.24	T	2.67	24.62
1915	2.51	2.06	0.89	2.28	5.54	6.57	7.42	4.73	7.26	0.64	2.22	2.67	44.79
1916	5.48	0.63	1.80	1.31	7.59	2.46	0.51	4.36	1.75	1.63	1.39	1.08	29.99

Values from September to December, 1898; all of year, 1899; from April to September, inclusive, 1900; and June to October, inclusive, 1901, are for Astoria, 13 miles distant.

SPRINGFIELD, SANGAMON COUNTY, ILLINOIS

1879	....	....	....	....	....	....	1.52	3.82	0.84	1.25	5.12	2.88	.....
1880	2.70	2.89	2.37	3.23	5.76	2.47	1.82	1.80	3.15	2.04	1.60	1.10	30.93
1881	0.84	5.85	4.45	1.96	2.86	4.96	3.37	4.03	6.43	10.02	6.93	4.81	56.51
1882	2.48	7.92	4.92	3.85	10.59	12.71	1.89	3.13	1.21	3.76	2.60	3.15	58.21
1883	1.96	7.53	1.36	4.42	6.61	3.40	3.77	0.95	1.06	6.08	3.48	3.17	43.79
1884	1.51	4.24	3.70	2.49	3.79	6.20	3.62	1.54	6.86	2.74	1.30	5.19	43.18
1885	2.81	0.94	0.17	6.36	2.78	4.18	1.82	4.82	4.47	6.30	1.44	2.52	38.61
1886	2.19	1.86	2.45	2.98	3.56	3.83	0.05	4.19	7.24	0.80	1.74	0.80	31.69
1887	1.09	4.26	1.41	2.89	1.92	3.07	1.01	1.05	2.89	0.85	1.36	3.35	25.15
1888	3.03	2.03	3.48	1.41	8.61	5.50	4.59	1.43	1.70	3.61	3.41	1.99	40.79
1889	2.13	1.64	1.97	0.71	6.64	3.65	2.14	0.78	4.74	2.86	4.05	2.00	33.31
1890	5.72	2.01	2.20	2.94	4.33	4.50	2.14	1.03	0.96	1.30	1.29	0.26	28.68
1891	1.16	2.59	3.21	2.81	1.96	2.11	4.44	4.65	1.38	1.88	5.49	1.59	33.27
1892	1.14	3.41	2.69	7.19	7.51	2.51	5.63	1.89	3.48	1.05	4.19	1.78	42.47
1893	0.65	3.47	4.19	10.23	7.41	1.99	1.60	0.28	2.15	0.16	1.57	1.08	34.78
1894	2.51	2.58	3.09	3.36	2.80	1.56	2.06	1.86	2.94	0.85	1.63	3.10	28.34
1895	1.12	1.03	1.61	2.49	2.55	3.49	5.58	2.76	2.80	0.27	3.23	8.08	35.01
1896	1.77	2.11	1.25	1.91	2.49	6.45	8.51	1.87	5.42	1.76	1.88	0.31	35.73
1897	5.91	1.15	4.47	3.85	2.19	4.11	4.16	2.86	0.35	0.52	4.94	3.07	37.68
1898	5.81	2.70	9.65	3.76	5.12	4.76	2.34	4.40	6.82	6.15	2.94	1.83	56.28
1899	1.51	2.52	2.95	1.12	11.81	2.45	1.51	3.81	3.33	4.08	1.84	1.87	38.80
1900	0.88	4.85	1.50	1.06	2.49	1.45	2.89	4.44	5.16	2.63	2.61	0.41	30.36
1901	1.80	1.31	2.96	1.23	1.88	5.34	0.58	2.92	1.95	1.78	1.06	2.70	25.51
1902	1.01	1.01	3.73	3.03	1.80	10.10	1.41	5.12	2.30	2.15	2.82	2.23	36.71
1903	1.44	3.05	1.47	3.99	5.28	2.18	1.59	2.92	2.48	1.50	0.98	1.50	28.38
1904	1.98	1.49	4.73	4.81	3.74	2.34	4.25	2.63	3.96	0.11	0.02	0.57	30.63
1905	2.13	1.18	1.48	2.02	2.28	2.31	3.99	4.70	2.40	3.66	1.60	1.72	29.47

SPRINGFIELD, SANGAMON COUNTY—*Concluded*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1906	2.99	2.18	4.02	2.26	3.70	3.03	0.93	4.88	3.77	1.46	3.13	3.14	35.49
1907	6.17	0.30	4.81	2.80	2.94	3.29	6.70	7.13	0.92	1.36	1.87	2.79	41.08
1908	1.77	4.28	2.21	4.48	7.27	1.38	1.37	2.62	1.22	0.29	1.17	1.62	29.68
1909	2.03	4.34	1.10	5.34	5.91	4.11	6.47	1.62	3.67	2.76	3.70	1.47	42.52
1910	1.68	0.94	0.18	2.81	4.39	4.58	2.63	0.78	5.34	1.74	1.57	0.86	27.50
1911	2.34	1.73	1.86	4.40	1.18	3.44	4.87	3.37	10.68	2.00	3.10	1.86	40.83
1912	1.08	1.56	5.18	5.88	4.40	3.13	4.47	2.87	1.42	3.49	1.48	0.31	35.27
1913	3.55	1.35	5.55	3.55	0.96	1.84	1.66	2.88	3.41	3.61	4.49	0.77	33.62
1914	2.13	2.58	1.01	2.99	1.11	1.69	1.39	3.32	1.82	2.08	0.49	2.20	22.76
1915	2.11	2.28	0.80	2.04	9.86	3.22	5.72	6.21	3.31	0.73	1.60	2.91	40.79
1916	4.77	1.00	1.89	1.43	4.21	3.14	0.31	4.34	3.35	1.97	2.26	1.22	29.89

WARSAW, HANCOCK COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1889	1.80	2.20	1.00	1.35	3.36	1.70	3.28	1.15	2.20	0.14	0.03	0.18	18.39
1890	1.80	1.00	0.17	1.50	2.50	2.09	1.75	1.07	3.17	1.08	1.85	T	17.98
1891	3.00	1.40	2.73	5.16	2.50	3.90	1.86	2.76	0.01	0.08	0.25	0.06	23.71
1892	....	....	....	....	....	...	....	....	....	....	....	....	....
1893	0.40	1.66	2.25	5.25	3.47	1.59	0.88	0.95	1.77	0.22	0.77	1.08	20.29
1894	1.74	1.20	....	1.08	0.78	1.41	0.38	0.01	1.60	....	....	....	.....
1895	....	....	1.29	1.68	2.66	3.08	4.29	....	....	....	....	....	.....
1896	....	....	1.50	1.67	3.05	2.39	....	....	....	....	....	....	.....
1897	....	....	2.37	1.20	0.53	3.93	....	....	....	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1906	2.58	2.84	2.97	2.58	1.86	1.87	2.11	4.38	3.78	0.83	2.28	1.73	29.81
1907	5.15	T	3.83	2.48	5.27	8.12	6.45	4.29	1.76	0.60	1.15	1.50	40.60
1908	0.36	3.51	1.67	1.86	11.11	5.85	4.18	3.16	2.08	0.87	3.34	0.71	38.70
1909	1.23	2.58	2.04	4.80	4.01	6.19	5.66	0.15	4.35	3.72	4.73	2.17	41.63
1910	0.51	0.97	0.43	2.82	7.81	1.79	3.51	0.83	2.59	0.95	0.27	0.81	23.29
1911	2.52	3.39	1.40	4.56	0.32	0.16	5.26	1.63	7.57	2.17	2.35	2.16	33.49
1912	0.25	1.22	0.80	3.41	1.90	3.20	4.18	3.31	1.80	4.31	1.81	0.41	26.60
1913	0.97	1.42	2.36	2.60	4.14	4.92	0.11	2.74	1.58	1.67	1.78	1.55	25.84
1914	0.92	2.14	1.56	1.45	1.80	3.66	2.00	1.55	7.23	2.09	0.26	2.20	26.86
1915	2.29	1.52	0.90	1.93	6.73	9.88	5.88	2.14	6.27	0.34	2.76	1.66	42.30
1916	5.81	0.92	1.71	1.80	8.30	4.98	0.26	4.52	2.87	3.04	1.92	0.83	36.96

WINDSOR, SHELBY COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1904	3.22	0.91	7.18	3.42	3.23	1.43	4.10	4.56	4.18	0.46	0.09	1.28	33.96
1905	2.00	1.57	1.86	2.22	4.40	3.46	8.06	1.34	1.14	4.21	1.52	2.14	33.92
1906	2.88	1.80	4.90	2.23	2.64	2.88	1.34	3.41	4.09	1.58	3.50	3.11	34.36
1907	4.99	0.48	3.88	2.22	3.82	4.40	5.63	4.60	1.57	1.30	1.92	3.22	38.03
1908	1.38	5.32	2.54	5.91	13.26	3.51	2.40	2.62	2.00	0.11	3.34	1.50	43.89
1909	2.42	4.16	1.94	9.23	5.49	3.95	6.80	1.20	2.94	2.76	3.73	2.25	46.87
1910	1.78	2.84	0.43	2.83	6.32	2.73	5.63	3.55	4.33	2.61	4.65	1.82	39.52
1911	2.22	1.91	1.87	4.50	4.46	1.49	1.92	4.18	14.76	3.78	2.80	1.56	45.45
1912	1.26	2.15	5.04	7.71	2.57	3.62	6.98	5.08	1.27	1.92	1.57	0.68	39.85
1913	4.86	1.86	6.87	2.46	0.41	2.18	0.92	2.12	3.20	4.26	4.28	0.60	34.02
1914	2.05	3.02	1.51	2.77	0.35	2.58	1.05	5.78	2.58	2.26	1.25	2.92	28.12
1915	2.11	1.87	0.87	2.30	8.80	5.87	8.19	8.28	3.02	0.81	2.19	3.97	48.28
1916	9.13	1.02	1.33	2.23	2.97	4.76	1.52	2.21	5.38	....	1.68	4.44	.....

PRECIPITATION FOR CENTRAL DISTRICT
AVERAGE OF ALL STATIONS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1856	1.30	4.69	0.90	2.18	2.47	3.20	3.58	3.15	3.62	3.50	3.39	3.95	35.93
1857	0.82	4.70	2.29	1.02	2.05	3.31	1.58	3.37	1.94	1.46	2.85	1.34	26.73
1858	2.07	1.66	2.37	4.32	7.30	5.57	6.60	1.96	2.95	3.70	3.16	2.57	44.23
1859	2.64	3.22	4.27	3.49	9.29	6.14	1.96	4.12	3.28	1.51	2.36	1.19	43.47
1860	...	...	...	...	...	...	...	...	...	...	...	...	....
1861	1.51	2.62	4.91	3.07	3.63	4.76	1.48	1.55	3.55	2.29	0.68	1.25	31.30
1862	4.89	0.63	2.23	6.87	2.00	4.34	5.34	1.70	6.15	1.62	2.20	4.98	42.95
1863	2.85	4.01	2.99	...	2.31	0.58	3.18	2.22	3.11	3.52	1.19	4.68	....
1864	2.35	0.73	2.16	5.55	2.09	1.27	3.64	1.58	3.29	2.43	3.78	2.75	31.62
1865	0.25	4.02	4.30	5.77	0.69	6.77	9.58	1.69	5.81	3.34	0.12	1.44	43.78
1866	3.63	2.73	2.44	4.47	3.54	1.48	3.60	3.09	8.69	4.91	0.51	2.46	41.55
1867	1.73	4.44	1.82	1.24	5.22	3.51	3.27	2.18	1.14	1.21	1.47	1.16	28.39
1868	1.06	0.49	6.22	5.48	6.31	2.64	3.56	3.69	4.09	1.59	4.07	2.41	41.61
1869	2.92	2.27	1.69	5.37	4.78	6.48	7.38	4.22	1.38	1.93	3.16	2.47	44.05
1870	2.04	0.47	4.40	1.50	1.69	2.33	3.12	4.74	3.00	3.67	1.85	1.90	30.71
1871	4.22	1.60	3.89	2.02	2.11	2.90	2.83	2.62	0.63	3.57	2.43	1.90	30.72
1872	0.51	1.41	2.87	2.62	2.79	7.61	5.68	2.20	2.92	0.56	1.15	1.30	31.62
1873	4.13	1.75	0.96	6.13	4.59	1.71	5.22	0.94	4.05	3.30	2.05	5.38	40.21
1874	2.94	1.77	1.67	2.89	2.21	3.81	3.34	5.25	3.92	1.39	2.53	1.09	32.81
1875	0.43	2.13	2.88	1.70	5.84	6.25	11.77	2.14	5.70	2.62	0.64	3.30	45.40
1876	2.13	1.48	4.57	3.68	4.70	5.46	7.12	5.02	9.58	2.02	2.27	0.21	48.24
1877	0.82	0.13	4.59	3.27	4.05	7.97	5.16	2.84	3.08	7.76	3.55	3.73	46.95
1878	0.86	3.27	3.96	2.79	4.19	3.41	3.11	5.67	1.25	2.58	1.55	2.89	35.53
1879	0.62	0.66	1.81	1.41	1.95	2.33	2.22	4.53	1.84	0.57	4.33	1.95	24.12
1880	3.88	3.32	3.09	4.94	6.01	2.73	2.11	3.08	2.78	1.89	1.74	1.49	37.06
1881	0.93	4.73	3.59	2.36	1.86	6.47	2.52	1.92	4.88	8.44	5.91	3.34	46.93
1882	1.94	4.76	4.21	3.72	7.50	9.31	2.81	3.64	1.22	3.25	2.45	2.16	46.97
1883	1.31	6.70	1.28	3.46	4.52	5.54	4.14	1.44	0.89	7.18	3.56	1.78	41.80
1884	1.34	3.67	3.02	2.56	3.81	4.97	3.04	2.23	5.59	2.99	1.76	4.62	39.60
1885	2.90	1.21	0.30	4.97	3.15	6.34	2.86	4.22	5.08	4.36	1.52	2.40	39.31
1886	2.70	1.51	2.64	2.34	3.96	4.71	1.22	4.13	6.02	0.78	2.32	1.22	33.55
1887	1.18	4.31	2.36	2.91	4.00	1.44	1.66	2.60	3.64	0.94	3.99	3.97	33.00
1888	2.60	2.17	3.41	2.09	6.35	5.79	5.26	3.18	1.95	2.83	4.22	2.61	42.45
1889	1.89	1.78	1.43	1.37	5.60	5.70	3.90	0.85	4.06	2.64	3.58	1.63	34.43
1890	4.91	2.32	2.34	2.72	3.38	4.38	2.99	2.46	2.85	1.77	1.96	0.47	32.55
1891	1.42	2.69	3.19	3.38	1.90	3.28	2.33	5.16	0.81	1.38	4.89	1.33	31.76
1892	1.62	3.00	2.07	7.43	8.15	4.06	4.29	2.27	2.43	0.99	4.04	1.55	41.90
1893	0.89	3.45	3.61	7.43	4.94	2.55	2.01	0.63	2.86	0.67	1.99	1.39	32.42
1894	2.30	2.27	2.85	2.71	2.58	2.35	1.71	1.64	4.13	0.88	2.18	2.07	27.67
1895	1.30	0.72	1.40	2.47	1.74	2.88	5.20	2.62	3.43	0.46	3.45	5.79	31.46
1896	1.08	2.00	1.65	2.19	5.05	4.39	7.36	3.43	5.89	1.10	2.23	0.59	36.96
1897	5.02	1.53	4.89	4.42	2.36	4.97	3.30	1.18	0.61	0.82	4.42	2.54	36.06
1898	4.49	2.01	7.45	3.29	6.50	3.79	2.63	3.63	5.62	4.19	2.46	1.49	47.55
1899	1.53	2.10	3.14	1.42	7.86	2.43	2.79	3.37	2.39	3.54	2.13	2.21	34.91
1900	1.05	4.83	1.64	1.37	3.84	3.57	4.22	3.94	3.90	2.89	2.63	0.73	34.61
1901	1.71	1.52	3.29	1.76	1.86	4.80	1.79	1.68	1.53	2.18	1.28	3.03	26.43
1902	0.96	1.31	3.65	2.69	2.92	9.36	3.71	5.58	3.76	2.41	2.90	3.02	42.27
1903	1.39	2.99	2.29	4.72	3.10	3.12	3.15	4.26	3.43	2.40	1.06	1.72	33.63
1904	3.18	1.15	6.31	4.41	3.62	3.33	4.69	3.85	5.19	0.52	0.25	1.38	37.88
1905	1.76	1.54	1.66	3.55	3.87	2.97	4.68	3.14	3.53	4.30	2.20	1.84	35.04
1906	2.84	2.04	3.88	2.43	2.91	2.96	2.25	3.99	4.35	1.32	3.55	2.90	35.42
1907	5.90	0.32	3.55	2.78	3.43	4.77	6.39	5.51	1.55	1.51	1.93	2.58	40.22
1908	1.36	4.24	2.53	4.65	8.86	3.17	2.89	1.70	1.50	0.54	2.60	1.32	35.36
1909	2.12	4.07	1.75	5.99	4.79	4.39	6.00	1.56	3.69	3.25	3.97	2.31	43.89
1910	1.90	1.69	0.31	3.15	6.04	2.57	4.10	2.22	4.72	2.34	1.58	1.27	31.89
1911	2.43	2.03	2.05	4.34	1.62	2.14	2.88	3.27	10.50	2.82	2.67	2.01	38.76
1912	0.90	1.55	3.74	5.48	4.66	2.96	3.73	3.76	2.20	3.06	2.00	0.70	34.74
1913	3.97	1.56	5.45	3.03	1.71	2.80	1.19	1.90	3.21	3.41	3.44	0.95	32.62
1914	1.78	2.33	1.32	2.49	1.63	1.98	1.83	3.28	3.73	2.62	0.72	2.12	25.83
1915	2.13	2.09	0.84	2.11	7.08	5.58	7.04	6.12	4.85	0.79	2.11	2.68	43.42
1916	6.78	0.85	1.78	1.55	5.63	4.37	0.96	4.20	2.70	2.29	1.96	1.85	34.92

PRECIPITATION FOR CENTRAL-SOUTHERN DISTRICT BY STATIONS

ALBION, EDWARDS COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1856	....	2.30	0.65	1.05	2.93	1.87	6.93	4.86	0.86	1.07	3.64	2.95	.....
1857	....	4.52	1.18	1.70	4.37	6.33	3.24	5.75	1.37	1.19	5.29	3.24	.....
1858	3.47	2.44	3.74	5.28	8.33	5.66	5.08	1.45	2.19	4.08	3.28	6.00	51.00
1859	2.26	4.60	4.02	5.91	2.78	2.64	4.14	1.62	3.62	0.93	4.17	4.38	41.02
1860	....	....	0.66	5.04	4.09	5.51	....	....	6.11	1.45	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1887	0.50	4.41	5.60	5.42	2.08	3.78	3.96	†0.40	3.20	0.79	3.55	3.60	37.29
1888	1.04	1.40	5.33	2.21	3.18	7.35	2.00	10.62	1.52	2.92	7.10	†4.01	48.68
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1893	....	....	....	....	....	....	....	....	....	....	....	0.85	.....
1894	2.59	3.35	2.48	3.09	5.32	0.46	2.12	3.75	2.14	2.35	T	4.07	31.67
1895	4.25	0.15	1.45	2.09	1.87	4.67	6.21	2.20	2.95	0.96	5.48	2.81	35.09
1896	0.73	1.30	4.81	1.23	13.21	6.13	4.89	2.54	5.68	2.05	3.35	0.46	46.38
1897	3.78	4.08	10.19	7.47	2.62	4.34	4.82	1.05	0.74	0.68	6.32	4.60	50.59
1898	6.00	1.91	12.39	5.27	6.68	3.35	5.51	3.42	3.57	3.25	2.27	1.47	55.09
1899	4.42	2.89	4.58	1.19	3.66	6.55	4.24	2.10	2.72	3.15	3.12	2.74	41.36
1900	1.80	4.24	2.30	1.55	5.20	7.81	4.19	1.36	4.91	2.28	3.85	1.79	41.28
1901	1.31	2.34	4.00	3.10	1.60	3.84	3.31	2.11	1.99	2.87	1.72	5.70	33.89
1902	2.00	0.86	2.86	1.85	4.15	4.98	2.33	3.02	3.03	0.93	4.92	4.99	35.92
1903	2.40	4.59	4.26	3.18	*2.05	3.05	4.19	4.92	1.28	4.55	1.41	2.01	37.89
1904	4.47	2.71	12.06	2.82	3.06	3.57	1.80	2.23	5.86	0.45	0.60	3.28	42.91
1905	2.70	1.63	2.76	4.21	4.29	1.83	5.88	2.05	2.37	6.06	2.62	3.56	39.96
1906	5.44	2.44	5.35	1.61	2.00	1.99	2.00	3.92	4.85	2.14	5.45	4.45	41.64
1907	8.65	0.71	4.74	3.51	4.12	4.81	3.92	6.98	0.32	2.21	4.02	5.20	49.19
1908	2.56	6.55	4.99	5.38	7.60	0.99	2.59	1.83	0.71	T	3.59	1.15	37.94
1909	2.53	5.36	3.59	4.91	3.34	7.28	4.93	1.01	4.62	2.68	3.10	3.28	46.63
1910	2.55	3.34	0.18	3.48	2.69	1.36	6.00	3.53	5.80	7.27	1.03	1.79	39.02
1911	1.33	2.09	1.52	5.56	1.14	3.90	1.08	1.92	4.08	2.16	2.92	2.30	29.95
1912	2.87	3.18	4.96	5.79	3.97	5.36	5.21	4.49	4.96	1.16	1.97	1.22	45.14
1913	9.37	1.17	11.64	3.67	2.65	2.86	3.13	4.01	3.73	3.74	5.00	1.18	52.15
1914	2.16	4.15	3.13	2.59	0.49	1.99	1.55	3.00	5.76	2.80	0.78	3.82	32.22
1915	5.75	1.55	1.06	0.74	6.26	6.14	3.25	7.57	1.73	1.09	3.50	5.50	44.14
1916	8.90	1.53	2.40	1.40	3.33	7.12	3.85	6.10	1.76	2.27	1.91	3.87	44.44

Values for 1856 to 1860, inclusive, are for West Salem, 10 miles distant.
*Value for Mt. Carmel, 16 miles distant.
†Value for Fairfield, 16 miles distant.

CARLYLE, CLINTON COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1885	....	....	....	3.50	3.72	5.29	0.62	4.06	6.77	4.39	2.97	3.49	.....
1886	8.12	1.40	2.42	2.09	2.85	3.10	1.34	3.78	5.48	0.72	3.91	2.67	37.88
1887	1.31	4.46	4.51	3.47	4.03	2.75	2.02	0.38	3.10	1.12	7.45	4.04	38.64
1888	2.54	2.77	3.46	1.77	3.95	7.59	3.61	7.18	0.87	2.47	3.58	2.78	42.57
1889	2.76	1.76	1.81	*1.50	4.93	6.41	4.86	1.09	3.43	1.83	5.32	1.48	37.18
1890	8.41	3.86	4.56	5.40	3.65	3.08	0.58	1.22	3.44	0.60	2.39	0.77	37.96
1891	1.45	3.75	2.57	2.62	3.18	5.30	0.73	2.37	0.87	1.69	6.05	1.05	31.63
1892	2.44	3.03	1.24	8.33	6.31	4.60	4.21	†2.64	1.09	1.28	4.23	1.86	41.26
1893	†0.84	†3.72	2.73	10.94	4.16	5.62	3.49	0.89	4.35	0.51	2.02	1.28	40.55
1894	2.17	2.17	2.68	2.20	3.47	1.44	2.06	0.84	4.97	1.44	0.68	2.92	27.04
1895	2.30	1.06	1.97	2.06	3.85	1.90	10.42	4.19	2.46	0.55	3.64	4.53	38.93
1896	2.39	2.62	2.46	1.57	6.67	3.36	6.92	3.55	6.86	1.93	5.31	0.39	44.03
1897	4.04	2.75	10.24	4.45	2.77	3.50	4.23	0.21	0.09	0.64	5.43	2.75	41.10
1898	3.98	1.76	11.93	3.91	9.55	6.48	6.23	4.66	2.87	4.21	2.44	1.80	59.82
1899	2.79	3.21	2.68	1.80	4.18	2.38	3.09	3.33	0.46	3.70	1.72	2.82	32.16
1900	0.56	2.87	1.95	1.32	6.25	3.70	....	1.25	5.64	2.88	3.85	1.70	.....
1901	0.72	1.81	3.85	2.78	2.38	3.47	0.27	2.65	1.09	2.80	2.24	4.21	28.27
1902	1.07	1.02	5.23	2.50	2.47	7.75	3.00	6.44	2.51	1.36	2.86	3.96	40.17
1903	1.58	3.31	3.01	3.64	3.39	2.13	0.95	3.23	1.95	3.97	0.85	2.12	30.13
1904	3.10	0.71	8.69	4.48	2.41	2.73	6.92	4.53	5.95	0.83	0.38	1.20	41.93
1905	2.35	1.53	2.60	6.99	4.44	5.81	11.21	2.93	5.94	5.79	2.09	2.45	54.13
1906	3.08	1.78	4.72	1.71	1.64	2.05	0.47	2.65	5.26	0.84	4.90	2.13	31.23
1907	6.51	0.94	3.56	8.95	3.81	3.27	4.36	4.65	0.89	2.86	2.41	3.70	45.91
1908	1.90	4.51	3.48	5.05	9.98	3.90	5.10	1.90	1.10	0.50	4.15	0.50	42.07
1909	2.76	4.81	3.70	6.77	4.33	5.43	4.55	T	4.25	4.33	6.00	3.41	50.34
1910	2.60	4.57	T	3.81	5.40	3.15	6.55	3.80	7.30	4.70	0.22	1.52	43.62
1911	1.50	2.60	3.60	7.85	1.60	2.72	0.95	3.99	8.79	2.59	3.51	2.15	41.85
1912	†0.57	†3.60	†5.30	†7.42	4.31	3.54	5.18	3.30	2.17	2.00	0.65	0.60	38.64
1913	6.21	1.09	5.68	3.37	1.20	3.27	0.89	0.63	4.57	4.36	5.52	1.86	38.65
1914	2.41	3.77	0.90	2.12	0.41	1.76	1.11	4.29	2.55	5.68	1.67	1.65	28.32
1915	3.86	2.51	....	....	....	....	....	....	....	....	....	....	.....

*Interpolated from surrounding stations.
†Values for Greenville, 19 miles distant.

EQUALITY, GALLATIN COUNTY, ILLINOIS

1899	5.79	3.12	5.35	3.09	3.86	3.53	10.04	1.80	3.14	4.25	2.32	2.83	49.12
1900	2.41	4.22	2.43	1.87	3.89	9.93	2.07	1.15	2.81	1.50	4.07	2.12	38.47
1901	0.65	1.76	3.26	3.06	1.65	3.02	2.11	3.39	0.85	4.74	1.54	3.53	29.56
1902	2.55	1.03	3.09	3.09	2.71	1.84	1.69	3.39	3.74	1.06	4.91	5.17	34.27
1903	2.67	4.44	7.27	3.53	2.60	2.40	1.83	1.62	0.60	2.17	1.29	2.74	33.16
1904	4.39	3.49	7.80	4.09	3.33	3.95	3.69	2.70	8.85	2.05	0.39	2.66	47.39
1905	2.77	1.70	3.05	3.38	4.91	2.21	9.40	3.78	1.88	7.72	2.82	3.30	46.92
1906	7.60	1.99	6.88	2.16	1.48	2.88	3.93	6.33	5.06	1.56	7.75	7.52	55.14
1907	10.90	1.35	4.13	3.25	6.47	5.53	1.96	8.07	1.67	3.88	4.96	3.73	55.90
1908	2.85	6.58	5.21	5.85	6.20	2.45	4.34	3.81	0.44	0.05	2.69	1.30	41.77
1909	3.48	6.14	3.98	6.29	3.08	2.56	8.19	0.46	2.55	1.98	3.83	3.86	46.40
1910	2.37	3.80	T	5.30	2.70	2.84	9.26	3.94	3.51	13.17	0.24	3.05	50.18
1911	1.53	2.23	2.03	10.30	1.19	1.51	2.43	6.97	5.07	2.58	3.06	3.61	42.51
1912	4.50	3.73	6.12	7.06	4.15	4.26	5.93	8.00	5.42	1.65	1.57	0.93	53.32
1913	9.89	1.34	7.77	3.07	1.22	0.62	2.35	1.61	3.68	3.98	3.93	1.54	41.00
1914	2.38	6.26	3.98	3.14	1.38	2.00	1.34	8.28	5.83	4.97	1.05	4.24	44.85
1915	5.19	1.94	1.22	1.20	7.87	6.85	4.66	6.26	5.14	0.69	4.49	9.08	54.59
1916	3.61	1.64	....	2.85	2.45	6.75	3.18	10.93	1.67	2.22	1.46	4.40	.....

FAIRFIELD, WAYNE COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1885	....	1.87	0.35	2.17	3.36	4.20	1.70	2.00	7.16	2.24	2.55	3.00	.....
1886	2.87	1.65	2.45	3.28	2.55	4.20	0.65	2.57	2.86	0.24	6.50	2.58	32.40
1887	2.06	3.96	5.93	4.63	5.33	1.73	2.49	0.40	3.85	0.70	4.87	3.96	39.91
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1888	3.70	2.00	3.49	1.04	2.18	0.12	1.93	5.91	0.44	1.08	1.99	4.01	27.89
1889	2.65	1.25	2.21	*1.10	4.40	5.75	4.72	1.75	5.49	*2.00	*5.30	*2.00	38.62
1895	....	....	....	....	....	....	4.51	1.78	2.86	....	3.97	3.64	.....
1896	1.15	1.69	2.88	1.24	6.81	8.29	6.00	1.36	6.64	2.43	3.98	0.48	42.90
1897	3.82	3.70	12.00	5.51	2.18	4.47	6.93	0.43	0.87	0.66	6.46	3.90	50.93
1898	5.06	1.20	11.99	5.01	6.69	5.05	5.05	4.91	4.35	3.80	2.39	1.64	56.64
1899	3.54	2.55	2.76	1.68	3.91	2.66	5.08	2.48	0.77	5.26	1.72	2.14	34.55
1900	0.93	2.94	2.18	1.17	4.24	9.07	3.82	1.75	3.94	1.63	3.45	1.64	36.76
1901	1.03	1.91	3.64	2.83	1.82	1.81	1.58	2.61	1.84	3.09	1.81	4.84	28.31
1902	1.48	1.00	3.65	1.78	2.97	4.55	1.83	3.29	1.55	0.76	3.18	4.11	30.15
1903	1.68	3.19	3.34	3.54	3.37	2.07	4.41	7.12	1.34	2.14	0.81	2.67	35.68
1904	3.04	2.15	9.72	2.86	3.90	2.78	4.90	6.83	6.04	0.34	0.70	2.63	45.89
1905	1.99	1.27	2.75	3.98	2.87	3 89	5.06	3.99	2.31	6.93	1.84	3.40	40.28
1906	3.99	1.90	3.39	2.28	0.70	3.45	2.45	3.68	5.43	2.95	4.50	4.14	38.86
1907	7.39	0.30	3.34	3.33	5.40	5.74	4.76	5.58	1.03	2.32	3.61	2.96	45.76
1908	†2.56	†6.55	†4.99	5.30	8.02	1.21	2.59	2.61	0.35	0.00	3.21	1.02	38.41
1909	3.02	6.83	3.91	6.18	3.17	3.95	5.35	1.05	4.10	1.86	3.60	2.34	45.36
1910	2.40	3.87	0.08	3.20	3.77	1.14	5.20	1.54	6.35	7.45	0.96	1.91	37.87
1911	1.40	2.19	2.00	6.21	1.20	3.89	0.84	2.53	6.80	2.01	2.64	2.91	34.62
1912	1.85	3.09	4.45	5.42	3.20	8.05	7.41	4.87	3.53	0.54	2.87	1.58	46.86
1913	10.18	1.05	12.43	3.70	2.30	1.48	1.41	3.46	4.65	4.08	4.40	1.84	50.98
1914	2.30	3.82	3.36	3.36	0.12	1.14	1.46	7.15	3.58	3.86	0.89	3.27	34.31
1915	4.04	2.54	1.00	T	6.95	5.59	3.41	....	2.16	....	2.61	4.71	.....
1916	3.76	1.30	1.79	1.16	3.60	5.24	1.85	5.94	3.90	2.66	1.63	2.92	40.75

Values for 1885 to 1889, inclusive, and April, 1908, to December, 1908, are for Fairfield.
Values for 1895 to 1907, inclusive, are for Cisne. Cisne is 14 miles from Fairfield.
†For Albion, 16 miles from Fairfield.
*Interpolated from surrounding stations.

FLORA, CLAY COUNTY, ILLINOIS

1869	....	....	....	10.90	5.10	6.40	6.10	2.70	4.30	3.00	5.70	3.80	.....
1870	4.90	1.30	3.30	2.50	3.00	4.30	6.30	5.10	1.30	3.50	1.80	2.60	39.90
1871	3.30	5.20	3.50	0.90	5.90	2.60	3.50	2.35	1.90	2.50	2.57	2.35	36.57
1872	1.05	1.70	1.90	4.20	4.70	3.10	9.50	2.70	1.70	1.00	0.50	1.70	33.75
1873	3.70	2.60	4.31	4.30	5.20	3.00	6.40	2.30	3.60	3.10	1.40	9.59	49.50
1874	3.20	4.60	6.30	6.10	3.60	3.40	6.20	9.80	1.50	2.20	3.80	4.30	55.00
1875	1.30	4.40	4.50	1.40	8.30	....	15.30	2.90	3.50	1.80	2.70	2.60	.....
1876	9.80	3.40	5.90	4.10	9.80	6.40	6.50	4.00	2.60	1.80	3.00	0.30	57.60
1877	1.70	1.20	3.15	4.60	6.40	11.40	2.40	4.50	1.60	4.60	3.60	3.00	48.15
1878	3.00	3.70	1.80	4.80	5.80	3.20	6.50	2.90	1.10	3.40	2.30	6.30	44.80
1879	5.10	1.40	5.10	2.60	2.10	1.20	2.30	5.50	1.00	2.90	5.00	3.20	37.40
1880	4.50	2.20	2.70	2.50	5.40	3.90	2.50	4.50	7.70	3.20	1.80	2.50	43.40
1881	....	1.85	3.00	1.80	1.71	7.50	....	....	....	....	....	....	.....
1882	....	....	....	....	....	....	....	....	....	....	....	....	.....
1883	....	....	....	....	....	....	....	....	....	....	....	....	.....
1884	....	....	....	....	....	....	....	....	....	....	....	....	.....
1885	....	....	....	....	....	....	....	....	....	....	....	....	.....
1886	....	1.02	3.79	4.55	1.25	7.57	1.89	4.69	3.52	0.73	6.75	3.03	.....
1887	1.48	6.24	6.56	4.90	3.51	3.56	3.48	2.26	2.77	1.17	5.23	3.65	44.81
1888	2.39	2.72	5.22	1.62	3.32	4.83	1.79	7.66	1.26	2.35	6.16	1.97	41.29
1889	2.60	2.49	2.23	1.16	4.88	11.49	6.14	2.00	5.66	1.95	5.45	2.11	48.16
1890	3.31	4.15	6.45	4.80	2.70	3.72	3.14	3.05	4.90	1.38	2.20	2.50	47.30
1891	1.50	5.15	3.25	1.87	2.00	5.00	0.20	6.10	1.40	1.80	6.60	2.20	37.07
1892	2.10	4.00	1.75	7.60	7.00	1.50	3.50	5.85	0.50	0.75	4.40	0.75	39.70
1893	1.25	3.20	4.20	10.85	4.95	2.75	0.65	1.20	....	....	2.90	1.33	.....
1894	2.41	2.43	2.97	3.20	3.77	1.91	2.96	1.75	4.09	1.60	0.68	3.00	30.77
1895	3.46	0.16	1.63	1.84	2.47	5.60	5.20	2.56	2.58	0.46	4.34	3.77	34.07

FLORA, CLAY COUNTY—*Concluded*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1896	1.05	2.02	2.75	1.55	4.05	5.20	6.26	1.04	4.23	2.31	3.92	0.31	34.69
1897	3.93	2.29	9.42	6.00	2.31	4.28	2.95	0.39	0.24	0.37	5.48	2.95	40.61
1898	4.86	....	....	....	....	....	....	....	4.76	4.06	2.41	1.52	.....
1899	2.94	2.69	3.48	1.49	2.73	4.56	3.53	2.57	0.60	4.54	1.71	2.65	33.49
1900	0.76	3.17	1.91	1.36	4.95	8.28	5.61	1.28	4.26	2.24	3.04	1.94	38.80
1901	0.86	2.19	3.46	3.07	2.04	3.91	2.09	2.80	0.84	2.95	1.82	5.18	31.21
1902	1.25	0.94	2.64	2.85	1.55	4.63	2.53	3.13	3.37	1.01	2.85	*4.11	30.86
1903	2.04	2.02	3.57	4.79	1.75	2.18	3.89	5.62	2.51	1.81	0.83	1.92	32.93
1904	2.37	2.00	9.50	2.45	3.40	5.14	3.41	3.02	6.26	0.37	0.86	2.15	40.93
1905	1.45	1.29	2.32	3.45	4.06	2.29	5.85	3.36	2.35	6.95	1.83	2.86	38.06
1906	*3.99	2.33	3.87	1.22	0.69	2.52	2.17	4.76	6.78	2.29	5.71	3.33	39.66
1907	7.59	0.63	3.09	3.63	4.02	6.08	4.44	4.98	0.95	1.89	2.92	3.33	43.55
1908	1.50	5.43	3.18	5.16	7.82	1.08	3.22	0.90	1.06	0.10	2.80	0.98	33.23
1909	2.46	4.40	5.55	4.79	4.08	5.59	6.57	0.09	5.79	4.50	4.28	2.45	50.55
1910	†2.97	3.66	0.24	3.93	3.17	3.23	5.03	1.60	5.03	7.17	0.78	1.27	38.08
1911	†2.06	2.20	1.62	5.41	†1.73	†7.93	†1.28	3.92	9.82	2.81	2.91	1.87	43.56
1912	1.42	2.21	4.08	4.92	4.63	3.25	9.53	3.53	2.61	2.28	2.10	0.81	41.37
1913	7.82	1.25	8.03	2.58	1.58	3.25	1.77	2.67	3.77	4.60	4.67	1.44	43.43
1914	2.81	4.46	2.96	2.31	0.21	2.22	1.19	4.36	5.20	3.11	1.10	†2.79	32.72
1915	....	....	....	0.27	7.50	6.39	5.62	7.71	1.49	0.26	2.55	....	.....
1916	....	....	....	1.28	4.26	2.48	1.13	....	....	....	....	....	.....

Values for 1869 to 1881 and 1890 to January, 1898, inclusive, are for Louisville.
Values for 1886 to 1889 and September, 1898, to December, 1908, inclusive, are for Flora.
*For Cisne, 11 miles from Flora. †For Olney.

GREENVILLE, BOND COUNTY, ILLINOIS

1882	....	....	....	....	2.96	9.45	3.68	....	....	....	....	....	.....
1883	1.00	4.50	3.66	5.05	6.25	4.21	7.50	3.52	0.03	9.52	6.62	2.46	54.32
1884	2.80	8.90	3.22	4.16	7.89	8.15	6.82	4.16	6.14	5.00	2.38	7.62	67.24
1885	2.08	1.87	0.03	5.90	5.19	5.06	3.97	4.92	6.86	5.42	2.95	3.45	47.70
1886	4.20	1.85	4.17	6.00	6.40	8.45	1.90	4.03	7.24	0.37	2.80	3.30	50.71
1887	....	....	....	....	....	2.97	2.21	1.31	4.09	1.39	6.38	4.68	.....
1888	2.68	2.75	3.64	2.28	5.00	6.52	6.06	3.92	1.47	2.62	4.59	3.00	44.53
1889	2.65	2.04	1.81	1.70	7.10	4.43	3.45	0.58	4.24	2.50	5.80	1.57	37.87
1890	9.61	4.50	4.21	4.62	2.58	2.49	1.17	2.60	2.89	1.00	2.06	1.64	39.37
1891	1.50	3.04	3.16	2.24	2.63	5.91	0.93	4.37	0.41	1.57	6.29	1.52	33.57
1892	2.62	4.41	2.87	7.91	7.79	5.37	3.10	2.64	2.08	1.53	4.26	2.28	46.86
1893	0.84	3.72	3.54	11.86	5.61	5.16	1.68	0.19	3.73	0.49	1.90	2.40	41.12
1894	2.45	2.45	3.53	3.52	3.31	1.51	2.69	2.31	4.74	0.78	1.89	2.73	31.91
1895	1.93	0.79	2.66	3.19	3.16	2.64	6.97	2.05	3.02	0.77	4.56	5.45	37.19
1896	3.54	3.32	2.37	2.26	7.28	5.03	2.26	1.50	5.82	2.80	5.86	0.82	42.86
1897	4.97	3.25	7.50	3.90	0.91	3.37	5.69	1.36	0.18	0.59	7.19	3.96	42.87
1898	3.97	4.23	9.73	3.58	6.51	4.28	4.37	2.61	3.80	5.58	2.26	1.47	52.39
1899	2.48	2.00	3.38	1.82	5.47	2.58	1.89	4.73	0.84	2.98	2.13	3.90	34.20
1900	1.41	4.86	2.09	2.27	7.63	8.39	2.51	0.51	4.27	2.04	4.05	1.20	41.23
1901	1.40	2.02	3.32	2.87	1.96	2.21	1.69	4.40	1.17	2.85	1.25	3.68	28.82
1902	0.61	1.37	4.19	2.69	2.63	8.15	2.02	4.41	2.43	3.24	3.41	3.92	39.07
1903	1.29	3.48	3.34	4.07	1.71	2.41	2.29	2.84	1.84	2.51	1.10	1.80	28.68
1904	4.25	1.10	11.43	4.19	3.52	5.33	5.12	5.98	5.04	1.31	0.20	1.84	49.31
1905	1.95	1.73	2.14	3.91	5.07	4.26	4.46	3.44	3.47	6.17	1.95	2.08	40.63
1906	4.50	3.07	5.35	2.72	3.04	3.65	1.37	2.03	5.52	1.48	4.25	2.61	39.59
1907	6.18	0.75	2.55	2.73	4.03	6.20	5.27	5.97	0.79	3.28	1.82	3.63	43.20
1908	1.46	5.68	3.93	5.35	8.73	5.29	4.94	2.25	0.55	0.02	2.72	0.97	41.89
1909	2.46	5.83	1.35	6.79	4.79	4.85	4.45	1.55	6.21	4.54	5.09	2.36	50.27
1910	1.93	2.65	0.07	2.55	3.76	4.17	8.01	3.35	6.47	5.05	0.32	0.94	39.27
1911	2.55	3.05	1.91	5.18	0.86	2.38	1.47	4.04	11.66	5.59	3.52	2.55	44.76
1912	0.57	3.60	5.30	7.42	3.22	*3.54	*5.18	*3.30	1.58	1.65	1.78	0.52	37.66
1913	5.01	0.97	8.33	2.42	1.04	5.37	1.86	0.72	3.52	4.55	5.48	1.26	40.53
1914	2.06	4.10	0.80	1.62	0.54	1.37	1.87	5.31	5.64	3.35	1.18	2.32	30.16
1915	2.84	2.66	0.62	1.52	10.08	5.56	5.12	11.19	....	....	1.74	4.26	.....
1916	9.01	1.70	2.05	1.42	3.25	4.13	2.04	8.31	2.34	1.32	2.18	2.26	40.01

*Interpolated from Carlyle.

MASCOUTAH, ST. CLAIR COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1882	3.50	7.25	5.00	2.65	4.75	5.81	5.12	2.37	4.25	3.66	5.74	2.37	52.47
1883	1.55	12.25	8.00	3.25	6.20	6.70	5.60	3.20	....	7.60	8.50	2.10	.....
1884	1.42	6.70	5.60	5.30	7.70	5.50	1.40	1.60	3.80	1.60	3.40	6.90	50.92
1885	1.10	0.71	0.44	6.30	2.30	8.10	5.00	4.20	7.10	6.60	3.10	3.74	48.69
1886	3.51	2.59	3.81	6.80	5.90	4.90	1.20	2.90	6.90	0.70	4.92	2.50	46.63
1887	1.58	4.70	4.80	3.40	3.80	1.50	3.50	1.20	2.70	1.50	5.50	4.20	38.38
1888	2.70	3.10	3.80	1.50	4.80	8.70	1.30	5.60	1.40	3.30	3.20	†2.03	41.43
1889	2.65	*4.80	0.80	2.20	4.90	5.00	6.40	1.30	4.20	2.40	4.80	1.60	41.05
1890	10.00	4.70	4.62	8.20	2.80	3.20	0.30	1.90	5.30	†0.85	2.60	1.30	45.77
1891	1.65	3.18	3.07	2.50	2.60	5.30	0.70	7.40	1.90	1.30	6.40	1.40	37.40
1892	2.70	3.00	2.45	9.20	7.70	6,20	3.50	1.10	1.40	1.40	3.60	1.55	43.80
1893	0.74	2.43	3.50	10.20	4.20	2.80	2.50	1.30	5.70	3.00	1.60	0.60	38.57
1894	1.17	2.21	2.40	3.50	4.40	1.70	2.00	1.50	4.50	0.80	0.40	3.63	28.21
1895	3.36	1.76	2.19	1.60	3.20	2.10	4.80	1.70	1.90	0.50	3.75	5.75	32.61
1896	1.54	2.41	2.89	2.30	9.70	5.20	3.80	1.40	5.80	1.90	4.20	0.10	41.24
1907	[a]7.35	[a]1.12	[a]2.39	3.85	8.19	3.33	3.61	4.50	1.74	2.82	2.76	3.45	[a]45.11
1898	4.03	2.89	11.33	4.21	6.84	5.62	4.84	5.57	3.80	4.42	2.43	1.48	57.46
1899	2.70	3.45	2.88	1.95	5.56	3.59	1.94	2.12	0.65	3.36	3.50	3.41	35.11
1900	0.40	3.99	3.40	1.80	5.50	5.17	2.65	1.47	3.32	1.99	3.84	1.44	34.97
1901	1.61	2.55	3.10	2.81	4.19	3.10	0.76	0.73	1.80	2.76	1.44	3.53	28.38
1902	1.36	0.83	4.78	2.70	3.15	5.00	2.59	4.40	2.52	1.55	3.53	3.75	36.16
1903	1.76	4.74	2.34	3.54	2.12	3.92	3.83	3.30	2.83	3.45	1.58	1.44	34.85
1904	3.15	1.71	7.78	4.11	3.25	6.90	5.05	7.50	4.25	0.88	0.70	1.52	46.80
1905	3.37	1.84	2.89	5.69	4.66	1.64	6.07	1.77	6.66	6.14	2.90	2.23	45.86
1906	4.28	3.35	6.22	2.00	1.50	3.04	0.90	2.33	5.12	1.85	[a]4.67	[a]2.09	[a]37.35
1907	[a]7.35	[a]1.12	[a]2.39	3.85	8.19	3.33	3.61	4.50	1.74	2.82	2.76	3.45	[a]45.11
1908	1.84	5.44	3.30	5.91	10.67	3.85	4.73	2.70	0.81	0.11	3.28	0.61	43.25
1909	3.04	4.13	4.40	5.62	4.48	2.90	7.63	0.07	4.16	3.22	4.56	2.68	46.89
1910	2.33	3.68	0.02	4.62	5.22	6.42	5.90	5.08	7.84	4.54	0.17	1.51	47.33
1911	0.76	2.89	2.24	6.41	1.68	1.82	1.58	3.70	5.85	3.51	2.68	2.00	35.12
1912	1.23	2.28	5.25	6.15	3.59	6.48	3.60	4.25	2.67	1.88	1.20	0.35	38.93
1913	5.10	1.20	3.81	2.86	1.26	1.92	2.13	1.98	2.97	5.15	3.90	1.60	33.88
1914	2.07	4.15	1.43	1.73	0.17	0.70	1.17	6.52	5.50	5.58	1.41	2.78	33.21
1915	2.42	2.43	0.57	1.44	8.29	9.07	4.69	12.98	1.70	0.81	2.95	3.17	50.52
1916	10.46	1.33	1.46	1.36	4.05	4.34	1.32	11.45	1.54	2.50	2.25	2.98	45.04

*Interpolated from surrounding stations. †For Collinsville, 16 miles distant.

[a] Values for November and December, 1906, January, February and March, 1907, and February, 1913, are for St. Louis.

MCLEANSBORO, HAMILTON COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1882	2.99	4.97	3.22	2.86	6.27	3.93	3.06	7.85	3.99	2.82	2.77	2.60	47.33
1883	2.30	8.27	3.32	3.19	5.20	9.13	3.14	2.54	0.00	9.28	6.64	3.50	56.51
1884	2.15	3.87	2.55	2.96	2.80	5.27	1.78	2.70	3.80	1.92	1.88	8.24	39.92
1885	4.20	1.10	0.89	2.22	2.51	4.83	1.74	3.67	6.02	3.66	2.56	3.50	36.90
1886	3.51	2.75	4.10	4.14	4.92	3.82	1.28	2.61	2.50	0.70	6.69	2.69	39.71
1887	0.98	3.94	3.10	3.43	3.35	3.45	3.05	0.19	1.45	0.77	3.08	3.29	30.08
1888	2.81	1.57	4.77	1.48	2.79	5.83	2.18	7.76	1.06	2.28	4.88	2.47	39.88
1889	3.20	2.36	1.95	0.88	2.80	....	4.31	3.02	4.33	1.52	5.74	1.77	.....
1890	7.12	5.28	5.94	4.03	4.10	2.10	5.53	7.05	4.69	1.13	....	1.38	.....
1891	*3.30	*4.50	2.08	*2.50	1.92	3.59	1.29	8.51	0.78	0.55	5.20	2.35	36.57
1892	1.48	3.44	0.93	7.50	6.92	2.30	1.85	3.97	....	2.11	4.25	0.98	.....
1893	1.12	3.55	3.25	6.02	5.96	4.54	1.89	2.12	2.44	2.35	2.48	1.51	37.23
1894	2.35	2.88	3.01	3.38	5.33	1.12	0.98	....	....	....	....	....	.....
1895	....	....	....	2.22	1.99	7.62	7.11	2.03	3.00	0.57	5.57	2.85	.....
1896	1.47	2.24	4.51	2.00	7.06	4.55	4.38	1.29	3.91	1.73	2.39	0.70	36.23
1897	4.23	4.00	11.29	7.27	2.53	5.52	3.43	1.70	0.63	0.45	5.85	5.12	52.02
1898	4.98	1.29	11.11	5.38	6.05	4.99	3.57	5.15	2.75	3.77	1.26	1.69	51.99
1899	4.96	2.61	4.33	1.95	3.82	4.91	5.16	3.14	2.02	4.03	2.46	2.36	41.75
1900	1.24	3.52	....	2.08	5.34	6.13	4.45	0.63	3.07	1.53	3.97	1.25	.....
1901	1.41	2.10	3.79	2.73	1.06	2.39	2.87	2.65	0.94	2.33	1.36	5.20	28.83
1902	1.93	0.96	3.83	2.18	3.30	2.68	2.21	2.71	2.44	0.85	3.65	5.27	32.01
1903	2.21	4.86	3.72	3.75	3.38	4.09	1.31	3.90	1.71	2.96	0.98	2.20	35.07
1904	3.78	3.49	8.89	3.93	3.32	4.67	5.48	2.12	10.11	0.40	0.94	3.17	50.30
1905	2.61	1.55	2.61	4.25	3.49	1.81	7.39	3.30	3.03	4.01	2.66	3.46	40.17
1906	6.20	2.74	5.38	1.46	0.50	2.89	1.92	4.35	5.43	1.76	5.32	6.01	43.96
1907	7.72	0.91	2.97	2.16	3.61	2.89	1.62	5.80	1.03	1.96	3.83	4.12	38.62
1908	2.35	7.55	4.45	7.10	6.60	0.65	2.83	2.17	0.41	T	3.23	1.33	38.67
1909	3.08	6.63	4.13	6.55	3.66	3.13	6.34	0.81	3.72	1.52	3.44	3.58	46.09
1910	3.09	3.09	T	2.45	2.96	3.13	3.57	2.57	5.03	7.84	0.56	2.06	36.35
1911	0.84	2.72	1.51	7.57	0.86	2.71	1.62	3.17	6.19	1.87	3.07	2.48	34.61
1912	2.92	2.75	5 40	6.45	3.10	4.68	6.76	4.48	4.88	1.49	2.65	0.93	46.49
1913	9.55	1.18	9.91	3.80	2.25	1.57	1.40	1.21	4.03	4.52	2.80	1.68	43.40
1914	*2.46	*3.54	*3.37	3.77	0.84	1.91	0.68	2.70	2.94	3.06	0.28	3.80	28.85
1915	4.49	2.63	0.95	1.64	8.28	6.83	3.82	8.87	1.87	1.04	3.07	6.25	49.74
1916	9.29	1.90	1.73	1.77	3.11	5.06	2.71	6.19	2.15	2.31	1.82	3.88	41.92

*Interpolated from surrounding stations.

MT. CARMEL, WABASH COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1876	9.35	2.71	5.04	3.33	1.79	6.24	1.68	3.81	2.68	1.74	2.10	1.95	42.37
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1884	....	....	....	....	....	....	2.05	1.29	5.62	2.51	1.97	7.59	.....
1885	3.81	1.48	0.95	2.71	2.85	4.38	2.38	5.16	8.57	2.96	4.28	2.20	41.78
1886	4.23	1.90	2.30	3.67	2.89	3.09	1.69	4.14	2.22	0.47	5.84	2.61	35.05
1887	0.87	4.53	3.96	4.52	4.29	0.75	4.14	1.61	2.91	0.91	4.42	2.80	35.71
1888	3.46	1.66	5.94	1.99	2.50	3.81	3.19	7.15	0.62	2.71	4.69	2.15	39.87
1889	3.24	1.76	1.47	2.04	5.60	4.72	3.60	2.13	3.84	2.29	7.11	2.82	40.62
1890	8.77	7.41	8.27	3.65	3.19	3.02	4.77	6.14	4.66	2.85	5.26	1.78	59.22
1891	2.83	6.04	4.70	2.05	3.19	3.53	1.57	2.11	1.22	0.48	5.48	3.25	36.45
1892	2.40	4.58	2.41	6.40	4.94	3.85	2.93	4.11	1.80	1.28	4.26	1.25	40.21
1893	2.61	4.81	4.00	7.93	4.56	5.84	1.41	1.44	3.43	3.18	2.62	2.02	43.85
1894	2.70	4.80	3.87	3.18	5.29	2.10	1.19	2.61	2.34	2.14	0.44	4.48	35.14
1895	5.84	0.50	2.61	3.14	2.43	1.83	5.77	1.91	2.96	0.42	5.75	3.55	36.71
1896	0.94	2.40	5.49	2.25	9.23	4.69	3.96	2.52	4.15	2.04	3.34	0.41	41.42
1897	4.52	4.10	10.22	6.20	3.14	3.15	3.10	0.59	0.60	0.58	6.69	4.88	47.77
1898	6.53	1.79	11.35	4.42	5.82	8.16	3.57	3.28	3.64	3.53	2.54	2.21	56.84
1899	4.93	4.01	5.16	1.15	3.35	5.65	3.47	1.39	2.03	4.89	1.82	3.33	41.18
1900	2.01	4.41	2.13	1.11	4.09	7.91	4.17	1.09	3.63	1.61	4.32	2.09	38.57
1901	1.63	1.70	5.20	3.84	1.84	4.44	0.32	1.46	2.14	4.43	1.74	6.07	34.81
1902	2.37	1.10	2.99	2.07	2.52	4.98	1.65	2.66	3.17	1.83	5.00	5.82	36.16
1903	3.58	5.46	4.44	5.82	2.05	6.22	3.46	2.71	1.38	3.96	1.89	3.44	44.41
1904	4.82	3.50	12.84	2.64	1.32	3.05	4.46	4.15	5.68	0.60	0.64	3.66	47.36
1905	3.28	2.28	3.14	4.82	4.82	2.39	7.48	3.54	1.26	7.14	3.00	3.32	46.47
1906	5.85	2.52	6.50	2.16	0.82	3.58	2.96	5.82	5.66	4.42	7.60	6.04	53.93
1907	9.39	1.28	4.50	3.48	3.80	3.64	3.42	6.88	0.64	2.02	4.72	4.92	48.69
1908	1.44	3.86	4.62	5.96	6.22	1.16	1.96	1.00	2.04	0.10	2.70	2.03	33.09
1909	3.20	6.06	3.99	5.90	4.42	5.69	4.54	3.88	3.16	3.74	2.60	4.88	52.06
1910	3.44	4.04	0.28	3.68	3.08	1.72	6.83	3.14	9.16	8.42	1.74	2.84	47.87
1911	2.26	3.02	1.82	7.10	2.00	4.34	0.88	2.28	5.44	2.80	3.36	2.86	38.16
1912	3.88	4.25	5.74	6.70	3.98	5.02	4.28	5.60	5.24	1.56	1.80	1.10	49.15
1913	9.76	1.16	12.13	3.86	2.06	2.58	1.84	1.28	2.88	3.45	4.60	2.54	48.14
1914	1.95	3.82	3.63	3.02	0.32	2.21	1.66	2.91	5.97	3.13	0.68	3.95	33.25
1915	4.67	1.39	1.17	0.63	6.33	4.74	2.31	7.28	1.70	1.02	3.34	3.94	38.52
1916	6.42	1.64	2.17	2.20	3.20	8.15	2.84	5.58	2.07	2.33	2.47	4.48	43.55

MT. VERNON, JEFFERSON COUNTY, ILLINOIS

1895	....	....	....	....	2.21	1.94	5.94	3.15	3.13	0.27	4.66	3.80	.....
1896	1.77	1.95	4.05	1.67	7.64	3.37	6.30	3.06	6.19	1.86	3.10	0.29	41.25
1897	3.57	3.39	10.18	4.47	1.30	7.49	3.00	0.77	0.41	0.56	4.00	1.89	41.03
1898	5.86	1.60	11.94	3.54	5.86	5.28	6.43	3.18	4.54	4.41	2.14	2.12	56.90
1899	3.26	3.38	2.90	2.27	4.19	1.94	4.98	2.40	0.90	3.95	1.30	2.19	33.66
1900	1.08	2.94	1.43	1.48	5.37	8.35	3.72	1.81	4.07	1.56	3.49	1.67	36.97
1901	1.37	2.54	3.79	2.51	1.23	2.32	0.69	3.29	1.53	2.25	1.79	4.05	27.36
1902	1.45	0.92	3.92	1.42	5.14	5.35	2.81	2.85	3.26	0.28	4.47	4.91	36.78
1903	1.66	3.37	3.15	3.66	2.54	4.89	0.94	2.87	1.94	3.20	0.84	2.68	31.74
1904	3.33	2.58	10.01	3.79	5.50	5.17	5.66	3.99	4.22	0.56	0.81	3.10	48.72
1905	2.42	1.41	3.18	4.92	3.55	2.14	7.97	2.75	4.24	5.87	2.52	3.89	44.86
1906	3.74	2.78	5.58	1.58	1.68	2.75	1.07	2.27	6.50	1.87	6.90	3.18	39.90
1907	8.15	1.00	3.38	3.22	4.39	5.50	3.98	6.61	0.97	3.49	3.64	3.50	47.83
1908	2.16	6.63	5.42	6.18	6.23	1.41	3.87	1.83	0.92	T	2.33	1.01	37.99
1909	3.82	5.17	4.98	7.50	4.45	7.13	4.03	0.30	3.72	1.55	3.23	2.81	48.69
1910	2.27	5.71	0.02	3.43	2.61	1.75	5.97	2.07	9.21	6.65	1.83	1.70	43.22
1911	1.23	2.80	1.59	6.25	1.06	2.08	1.44	3.68	7.51	2.62	2.63	3.10	35.99
1912	1.38	4.25	3.94	3.81	4.67	5.64	5.98	4.68	3.60	0.74	2.46	0.69	41.84
1913	8.76	1.05	8.84	2.94	1.89	4.57	1.44	0.80	4.20	4.66	3.84	1.83	44.82
1914	2.65	3.57	2.86	2.34	0.35	1.54	0.51	6.38	3.95	4.93	0.20	3.40	32.68
1915	4.16	2.48	0.76	0.92	7.61	4.60	2.73	9.87	1.68	0.50	2.34	4.76	42.41
1916	8.25	1.36	1.55	1.11	4.35	4.02	2.05	7.91	2.65	2.37	1.64	3.33	40.59

OLNEY, RICHLAND COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1887	1.16	....	6.00	5.44	4.44	....	2.51	1.82	2.80	0.75	5.52	....	.....
1888	1.98	1.57	5.25	1.80	2.61	4.41	5.64	9.78	0.91	2.82	7.06	2.65	46.48
1889	2.73	2.66	1.91	1.23	4.70	5.71	7.59	3.32	5.09	2.71	4.66	3.96	46.27
1890	7.21	4.48	6.52	3.81	3.95	4.37	1.25	4.44	5.84	1.38	2.46	2.16	47.87
1891	2.06	5.48	4.23	2.74	1.30	3.54	0.56	4.41	1.33	1.45	6.71	2.37	36.18
1892	1.85	4.15	1.56	7.85	5.11	2.07	4.14	3.26	0.76	0.32	3.39	1.03	35.49
1893	0.64	3.73	4.05	10.44	4.14	5.38	0.96	2.65	3.95	1.97	3.10	1.74	42.75
1894	2.27	3.19	3.06	2.80	5.20	1.39	2.28	2.63	2.42	2.02	0.47	3.34	31.07
1895	4.25	0.45	1.40	2.15	1.78	3.00	5.85	1.48	2.06	0.13	4.40	3.47	30.42
1896	0.89	2.21	3.07	1.52	6.13	3.82	8.67	0.47	4.57	1.69	5.56	0.46	39.06
1897	3.77	2.92	11.77	6.49	2.75	4.48	2.85	0.40	0.71	0.52	6.57	3.86	47.09
1898	5.22	1.98	10.97	5.00	4.33	1.10	4.76	3.58	4.41	3.06	2.14	1.89	48.44
1899	3.98	2.81	3.03	0.99	2.93	3.95	2.82	2.92	0.93	2.86	1.82	2.66	31.70
1900	0.93	2.99	2.37	1.21	3.14	6.29	4.15	1.36	3.67	1.58	2.54	1.67	31.90
1901	1.00	2.88	4.24	2.58	3.09	2.56	0.25	2.45	1.07	2.49	1.27	5.16	29.04
1902	1.41	0.69	2.64	1.51	1.85	4.70	3.07	3.20	2.14	1.33	3.51	4.01	30.06
1903	2.94	4.02	3.66	4.96	0.94	3.57	4.46	2.49	0.42	1.99	1.35	2.87	33.67
1904	4.00	2.05	10.60	2.20	6.56	3.06	2.27	1.76	6.13	0.53	0.94	4.02	44.12
1905	2.89	1.29	2.61	3.74	3.11	2.09	4.13	4.40	2.07	8.70	1.65	2.41	39.09
1906	3.37	2.33	4.84	1.93	1.29	3.21	3.97	3.77	7.75	2.98	5.55	4.19	45.18
1907	7.53	0.52	4.50	3.92	6.38	5.77	7.08	6.37	1.35	2.43	3.57	3.52	52.94
1908	1.98	5.17	3.76	5.07	6.63	1.01	3.52	1.02	0.88	0.24	3.81	1.05	34.09
1909	2.77	6.42	3.80	3.44	3.52	5.57	5.03	0.81	3.94	3.60	4.18	3.23	46.31
1910	2.97	3.57	0.27	3.79	5.18	3.07	4.30	2.10	6.72	6.55	2.32	1.78	42.62
1911	2.06	2.41	2.10	6.81	1.73	7.93	1.28	2.40	12.23	3.05	3.03	2.62	47.65
1912	1.75	2.08	4.56	4.50	5.84	2.32	4.64	*3.58	*2.61	*2.23	1.31	1.09	36.51
1913	9.01	1.10	9.57	3.23	2.37	1.48	2.18	1.97	4.04	3.72	4.89	1.41	44.97
1914	2.77	3.60	2.75	3.73	0.77	1.76	3.63	7.83	2.48	3.06	0.89	2.79	36.06
1915	3.63	2.91	1.11	1.21	6.65	5.53	5.76	8.82	1.58	0.75	3.54	4.34	45.83
1916	10.05	1.14	1.66	1.09	4.42	7.04	1.30	7.92	3.61	2.32	1.15	2.11	43.81

*Interpolated from Flora.

PALESTINE, CRAWFORD COUNTY, ILLINOIS

1882	....	....	....	....	....	5.60	1.92	3.27	2.17	1.68	2.02	3.88	.....
1883	2.10	8.47	3.62	3.40	2.09	4.43	8.30	1.95	0.35	7.58	7.65	4.10	54.04
1884	1.90	4.40	1.79	3.05	5.38	5.09	3.34	1.75	5.29	1.40	2.27	5.84	41.50
1885	3.25	1.65	0.46	4.70	2.85	3.40	2.40	3.08	3.73	2.59	2.61	2.33	33.05
1886	2.88	1.70	2.55	5.36	3.56	6.15	3.69	3.21	2.21	0.26	5.52	2.60	39.69
1887	1.01	4.83	4.18	3.84	5.30	1.30	1.59	2.60	2.44	0.88	4.21	3.40	35.68
1888	1.75	1.47	4.72	2.08	2.40	*4.98	2.30	4.50	0.76	2.55	5.67	2.16	35.34
1889	2.72	2.20	1.71	1.37	4.00	5.50	2.46	2.95	5.44	2.33	5.43	1.93	38.04
1890	9.20	4.96	5.65	4.07	4.31	2.58	2.35	3.56	5.38	2.97	2.74	1.90	49.67
1891	2.00	5.68	4.15	1.84	0.76	*2.87	0.86	6.30	1.33	1.33	5.65	2.18	34.95
1892	1.15	4.97	1.88	9.18	6.60	3.53	2.47	3.02	1.60	1.08	4.43	2.00	41.91
1893	2.00	4.39	3.40	9.12	3.70	4.60	0.71	2.71	3.33	3.37	3.12	1.53	41.98
1894	2.21	5.01	1.97	2.88	5.60	2.68	1.85	3.92	2.94	2.15	1.05	2.22	34.48
1895	4.37	*0.63	1.66	3.65	3.43	2.05	7.04	3.10	1.46	0.57	4.85	3.69	36.50
1896	1.00	2.47	2.19	1.07	3.90	7.33	7.76	3.22	4.30	2.60	5.30	0.54	41.68
1897	3.38	2.95	11.02	5.60	3.45	3.61	2.08	0.01	1.60	1.09	6.33	3.18	44.30
1898	5.33	1.56	11.45	3.82	3.15	4.06	2.80	4.29	7.42	4.61	3.15	2.33	53.97
1899	3.74	1.95	4.96	1.91	3.28	3.40	2.98	3.12	1.47	2.99	2.13	3.62	35.55
1900	1.95	4.55	4.02	1.47	3.86	6.77	11.96	2.00	4.43	1.59	4.06	2.64	49.30
1901	1.03	2.95	5.57	2.52	1.34	6.42	0.97	2.75	1.38	2.79	2.00	5.34	35.06
1902	2.46	1.43	3.77	2.23	4.60	7.73	1.63	6.22	3.14	2.40	3.37	3.78	42.76
1903	2.60	3.97	4.47	5.41	0.52	2.51	4.51	6.83	0.73	2.66	1.95	1.42	37.58
1904	4.10	2.30	9.76	1.95	3.16	2.22	3.81	2.78	5.45	0.10	1.10	4.48	41.21
1905	2.00	1.45	2.82	3.36	3.67	1.46	6.28	2.94	2.44	8.54	1.80	2.61	39.37
1906	4.81	2.25	5.07	1.32	1.40	1.66	3.56	9.97	4.05	1.09	5.05	3.35	43.58
1907	6.55	0.10	5.55	3.54	4.15	4.48	4.15	7.32	0.60	2.70	2.90	3.34	45.38
1908	1.60	5.89	4.13	4.64	9.58	1.96	2.48	0.87	1.78	0.10	3.23	1.40	37.66
1909	*7.76	*3.10	4.51	3.47	3.18	6.42	5.24	0.73	1.83	3.11	3.70	3.61	46.66
1910	2.71	3.67	0.19	2.58	3.37	2.27	11.11	0.59	4.51	6.64	2.45	2.19	42.28
1911	2.95	2.56	2.33	5.18	1.42	4.35	2.26	1.78	11.52	4.19	2.26	2.94	43.74
1912	1.23	2.16	4.17	4.53	5.69	3.62	6.83	5.30	5.30	1.62	2.59	1.30	44.34
1913	7.02	1.61	8.05	2.53	0.79	2.36	3.44	4.36	3.23	3.08	5.35	1.15	42.97

*Interpolated from surrounding stations.

ST. LOUIS, ST. LOUIS COUNTY, MISSOURI

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1830	....	....	....	....	....	....	4.97	12.25	5.16	5.79	1.28	0.55	.....
1831	2.08	1.06	4.58	4.39	1.95	1.84	1.88	2.51	1.99	6.76	4.08	3.68	36.80
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1836	....	....	....	....	....	....	3.66	6.51	5.90	2.59	4.20	5.02	.....
1837	0.84	1.35	3.18	2.34	3.00	3.46	2.43	2.73	2.85	0.79	1.96	2.01	26.94
1838	3.72	1.11	1.51	3.36	1.68	3.73	3.13	4.47	0.06	3.06	2.09	0.44	28.36
1839	2.21	2.50	2.59	5.46	7.93	7.26	5.71	2.89	2.45	3.96	2.48	2.00	47.44
1840	1.80	1.38	2.10	3.31	4.58	6.27	2.36	7.15	3.96	6.30	1.73	0.71	41.65
1841	0.84	0.88	4.99	3.85	2.38	1.67	3.09	5.68	3.22	6.81	5.44	3.93	42.78
1842	0.45	3.90	2.21	3.48	3.22	5.12	1.76	2.64	2.17	2.57	2.38	2.39	32.29
1843	2.34	1.90	3.49	4.87	4.15	3.95	2.49	1.32	2.19	1.55	4.82	1.72	34.79
1844	3.36	1.73	4.84	8.86	11.26	6.85	3.13	0.45	0.30	2.25	1.17	1.61	45.81
1845	1.83	1.07	3.18	2.28	4.42	10.01	4.75	6.23	1.03	1.16	1.10	0.93	37.99
1846	2.98	1.27	1.27	4.84	3.75	5.21	0.84	4.73	4.84	2.71	2.11	10.90	45.45
1847	2.12	3.58	2.28	3.98	4.36	8.61	5.37	0.90	3.26	8.74	8.63	0.89	52.72
1848	1.86	2.27	6.61	3.16	8.10	17.07	5.37	9.74	1.12	2.41	1.91	5.74	65.36
1849	4.18	0.56	2.70	2.64	2.71	6.46	9.40	5.15	5.81	2.17	2.11	1.82	45.71
1850	1.94	4.10	5.63	7.68	7.47	1.47	4.83	2.10	3.74	2.71	6.24	2.59	50.50
1851	0.61	6.74	3.14	4.70	2.83	6.19	1.77	8.97	0.49	1.51	1.99	3.90	42.84
1852	0.99	2.12	7.67	2.28	5.19	10.25	3.36	1.60	1.47	5.26	3.29	3.48	46.96
1853	0.52	1.67	0.79	3.24	3.64	3.28	4.10	5.48	4.67	0.96	1.51	1.03	30.89
1854	1.18	3.11	7.49	7.60	6.80	3.21	0.92	1.30	1.44	4.15	1.94	1.49	40.63
1855	4.66	0.70	2.89	2.65	7.46	4.27	5.17	6.53	3.89	3.89	5.16	3.10	50.37
1856	1.03	3.64	1.06	6.35	3.03	1.24	4.61	6.32	3.51	2.10	4.90	4.29	42.08
1857	0.41	7.74	1.80	1.72	4.81	3.71	2.82	4.15	3.18	3.02	3.80	1.87	39.03
1858	3.42	2.12	3.96	6.07	10.64	6.69	8.08	2.87	3.86	7.73	4.92	8.52	68.88
1859	2.82	5.35	7.32	4.89	6.60	11.02	5.54	2.93	4.44	1.30	5.43	3.76	61.40
1860	1.80	2.60	1.16	2.08	2.29	6.58	2.97	2.96	2.11	1.58	1.63	2.03	29.79
1861	1.16	2.01	7.38	3.18	4.39	4.96	2.04	3.44	4.14	2.85	1.39	1.09	38.03
1862	4.01	0.80	4.11	4.82	2.51	2.85	3.61	1.32	6.27	3.73	3.59	6.38	44.00
1863	4.11	3.99	3.02	1.55	2.68	3.16	2.51	6.93	1.56	4.76	2.15	4.03	40.45
1864	2.74	0.82	1.71	5.58	3.90	0.41	3.60	4.91	2.82	3.15	5.25	2.72	37.61
1865	0.87	3.75	8.61	3.31	5.66	5.21	7.94	1.97	2.60	3.33	0.00	3.63	46.88
1866	4.16	2.24	2.80	1.56	2.24	5.59	3.68	3.71	10.53	2.01	1.37	1.87	41.76
1867	2.28	4.81	2.37	0.53	8.26	5.64	3.71	2.29	0.17	1.31	2.74	3.65	37.76
1868	1.71	0.55	7.66	7.08	3.96	1.58	2.03	8.53	5.25	2.11	2.04	3.09	45.59
1869	2.02	2.49	4.24	4.61	3.60	6.25	2.49	5.51	1.70	3.42	7.48	3.16	46.97
1870	2.25	0.33	2.76	2.39	2.78	1.33	1.59	6.55	1.14	3.35	1.94	2.76	29.17
1871	2.53	2.92	1.27	0.49	3.15	2.51	1.64	3.55	0.25	2.07	1.83	1.17	23.38
1872	0.64	1.15	2.48	2.77	6.04	4.28	4.59	0.93	3.33	0.55	2.01	1.70	30.47
1873	3.53	1.52	2.10	6.88	5.73	6.68	5.96	0.07	3.02	3.27	1.64	5.10	45.50
1874	3.14	3.66	4.36	3.44	3.70	2.00	5.71	4.70	2.30	1.09	2.32	1.46	37.88
1875	0.54	2.59	4.08	2.53	5.48	10.84	9.50	2.66	0.24	1.23	0.89	2.42	43.00
1876	4.75	2.86	6.90	2.25	3.13	3.43	5.90	5.03	7.63	1.66	1.74	0.18	45.46
1877	1.24	0.88	3.41	3.03	3.11	8.69	2.88	2.61	3.56	4.92	3.76	3.34	41.43
1878	3.36	1.69	2.79	6.74	4.63	2.40	3.92	4.75	3.42	3.27	1.38	3.48	41.83
1879	1.64	1.48	1.92	2.31	0.95	4.04	1.97	2.23	1.34	0.68	4.30	2.84	25.70
1880	3.83	2.65	2.51	3.31	3.44	2.56	5.17	1.53	3.10	2.09	2.67	1.80	34.66
1881	0.49	4.16	1.95	3.14	3.96	2.74	2.13	0.81	3.14	7.21	6.74	1.40	37.87
1882	2.80	8.94	3.49	3.58	4.55	4.53	3.84	2.20	1.78	2.44	3.24	1.81	43.15
1883	0.94	5.88	2.29	3.31	2.89	5.04	4.31	3.34	0.01	6.60	3.71	1.78	40.10
1884	0.79	4.43	3.00	4.15	2.68	4.52	2.86	1.21	6.04	2.48	2.30	6.18	40.64
1885	3.26	0.87	0.40	4.84	2.80	7.68	2.58	2.96	8.98	7.51	1.68	2.03	45.59
1886	3.11	1.71	3.04	2.10	7.84	7.09	0.55	2.44	9.60	0.85	3.36	2.65	44.34
1887	0.65	3.68	3.54	4.36	5.27	2.54	2.74	1.14	2.47	0.76	4.61	3.54	35.30
1888	2.15	2.39	3.79	1.88	3.81	8.09	2.09	6.66	1.31	2.59	4.40	2.01	41.17
1889	3.04	4.78	1.62	1.63	3.80	4.72	2.02	0.85	3.54	1.65	4.48	1.03	33.16
1890	7.47	2.86	5.99	4.05	5.81	3.18	0.37	2.43	1.80	0.86	1.55	1.32	37.69
1891	1.35	2.95	2.29	2.29	2.73	5.97	1.50	2.75	1.43	0.65	5.30	1.32	30.53
1892	1.52	4.89	1.92	7.60	7.87	2.73	4.64	1.75	1.59	1.66	3.46	1.99	41.62
1893	0.33	2.98	5.10	10.84	5.42	3.49	2.49	0.65	3.69	1.66	1.36	1.32	39.33
1894	2.56	2.88	2.69	2.68	3.61	1.12	1.35	1.66	3.11	1.56	1.49	2.73	27.44
1895	1.65	0.48	2.82	0.46	3.16	2.46	7.26	2.08	2.01	0.23	3.93	4.66	31.20

ST. LOUIS, ST. LOUIS COUNTY, MO.—*Concluded*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1896	1.43	2.81	2.03	2.43	9.12	4.57	4.67	2.12	2.42	1.20	3.70	1.05	37.55
1897	3.75	2.67	8.25	4.66	1.59	5.32	3.28	0.66	0.09	0.31	6.21	3.48	40.17
1898	4.53	1.71	7.73	3.85	8.55	3.85	7.44	0.87	3.23	4.84	2.07	1.03	49.20
1899	1.66	3.40	3.96	1.98	6.32	2.32	4.54	2.77	1.27	2.89	1.95	1.55	34.61
1900	0.65	5.09	1.45	1.83	4.47	2.62	3.85	1.30	2.68	2.07	3.10	0.40	29.51
1901	1.12	1.86	2.94	2.35	2.69	3.92	1.47	0.76	0.64	2.12	1.21	3.72	24.80
1902	1.18	0.83	4.50	2.49	3.04	7.86	2.34	5.20	1.98	2.00	3.20	3.81	38.43
1903	1.76	3.14	3.20	2.79	2.08	5.71	2.68	6.16	3.06	1.37	0.61	1.25	33.81
1904	3.15	0.84	7.87	3.25	2.88	4.04	3.09	2.62	2.97	0.50	0.54	1.36	33.11
1905	2.47	1.12	2.35	2.32	4.67	2.72	4.42	2.58	5.56	6.64	1.63	2.06	38.54
1906	3.57	2.92	4.53	1.98	2.61	2.80	0.98	3.72	4.40	1.25	4.67	2.09	35.52
1907	7.35	1.12	2.39	3.65	5.57	4.96	3.32	4.36	1.57	3.15	1.89	2.06	41.39
1908	2.03	3.39	3.48	3.84	7.72	3.02	4.24	1.55	1.24	0.21	2.83	0.64	34.19
1909	3.20	3.94	3.69	6.18	5.99	2.63	7.34	0.66	4.22	3.40	4.36	1.89	47.50
1910	2.73	3.22	0.14	4.09	5.23	4.24	4.21	1.90	6.09	3.98	0.30	1.18	37.31
1911	0.85	3.02	2.22	7.46	2.26	1.34	0.64	3.51	7.09	2.63	3.44	1.67	36.13
1912	1.31	2.80	5.85	7.84	4.29	6.93	5.29	2.65	2.84	2.61	1.76	0.42	44.59
1913	4.34	1.20	7.97	3.57	1.53	1.55	3.61	1.50	4.50	4.08	3.12	1.62	38.59
1914	2.21	4.63	1.25	1.92	0.69	0.10	1.52	5.42	6.68	7.45	1.53	2.28	35.68
1915	2.83	2.30	0.44	1.20	7.67	9.77	6.02	11.43	1.41	0.90	1.97	3.34	49.28
1916	3.53	1.78	1.83	1.78	8.00	3.97	1.20	10.69	2.69	1.64	2.53	2.16	41.80

TILDEN, RANDOLPH COUNTY, ILLINOIS

1887	1.65	....	4.62	2.66	4.49	2.27	1.93	0.88	2.97	2.28	7.09	3.41	.....
1888	2.17	3.27	5.18	1.82	2.79	7.23	1.30	10.22	2.26	3.55	4.48	2.49	46.76
1889	3.55	2.35	1.68	*1.60	3.68	3.11	3.41	3.59	2.27	1.51	5.15	1.66	33.56
1890	8.12	3.98	7.33	6.54	2.92	1.38	1.73	7.06	4.34	0.62	2.38	1.59	47.94
1891	1.88	5.22	2.00	2.74	2.87	4.27	0.65	3.43	0.66	1.93	6.23	1.83	33.71
1892	1.67	4.09	1.52	11.03	5.91	3.22	2.95	2.22	2.59	2.44	5.95	2.19	45.78
1893	0.28	1.77	2.74	9.23	4.09	4.14	2.64	2.39	3.07	6.55	1.68	1.23	39.81
1894	2.30	2.60	2.81	3.93	3.57	1.17	3.15	1.32	3.91	1.22	0.77	2.84	29.59
1895	1.50	0.45	2.53	1.03	3.08	3.84	3.75	2.56	2.65	0.41	4.30	5.45	31.55
1896	1.33	2.36	3.69	3.64	3.56	2.84	6.06	1.47	3.15	1.56	3.43	0.22	33.31
1897	3.16	2.37	10.51	3.55	1.57	4.88	0.93	0.49	0.27	1.13	4.54	4.13	37.53
1898	3.83	1.94	9.95	3.40	5.93	5.09	6.91	4.85	4.81	6.36	1.88	1.97	56.92
1899	2.16	2.91	2.27	1.30	3.04	2.72	5.79	1.64	0.93	2.75	1.38	1.89	28.78
1900	0.63	3.05	1.25	2.37	2.79	6.66	3.42	1.50	3.22	2.20	3.38	1.19	31.66
1901	0.99	1.96	3.03	2.11	2.32	1.37	1.33	1.05	2.37	2.28	2.40	3.59	24.80
1902	0.96	0.76	4.47	2.04	4.70	2.82	2.71	4.15	3.79	1.42	4.09	4.33	36.24
1903	0.95	2.89	3.06	3.13	2.69	2.51	1.35	3.58	1.63	4.32	2.05	1.69	29.85
1904	2.39	1.83	8.66	4.62	3.14	5.18	2.23	5.33	6.47	0.57	0.86	1.66	42.94
1905	2.61	1.52	3.79	4.63	3.09	0.26	11.34	3.20	5.19	3.91	2.02	2.92	44.48
1906	4.51	2.64	4.36	1.77	2.80	2.98	1.72	4.42	7.42	1.52	5.70	3.23	43.07
1907	6.13	1.16	2.66	3.73	5.40	4.41	2.60	5.11	3.99	3.01	3.17	4.05	45.42
1908	2.03	5.61	3.94	7.02	7.08	2.30	5.26	2.74	1.32	0.10	4.34	0.72	42.46
1909	2.95	4.27	3.96	7.53	3.97	3.76	6.14	0.07	5.47	1.97	5.56	2.86	48.51
1910	2.45	3.27	0.03	3.23	5.46	2.90	5.16	4.06	4.47	4.62	1.19	1.58	38.42
1911	1.17	2.52	2.08	7.98	1.46	0.91	1.67	3.92	6.74	3.71	2.71	2.72	37.59
1912	1.96	2.25	5.18	5.88	4.38	3.95	3.41	4.50	3.22	3.01	1.01	0.61	39.36
1913	10.69	1.38	....	3.05	2.60	2.76	3.32	1.87	4.21	3.52	2.86	1.59	.....
1914	3.02	3.61	2.43	2.58	0.50	0.95	1.03	6.39	3.08	6.27	1.07	3.72	34.65

Values from 1887 to February, 1898, inclusive, are for Jordans Grove.
Values March, 1898, to 1908, inclusivie, are for Tilden.
Values from 1910 to 1916, inclusive, are for Sparta, in the same county.
*Interpolated from surrounding stations.

PRECIPITATION FOR CENTRAL-SOUTHERN DISTRICT
AVERAGE OF ALL STATIONS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1856	1.03	2.97	0.86	3.70	2.98	1.56	5.77	5.59	2.19	1.59	4.27	3.62	36.13
1857	0.41	6.13	1.47	1.71	4.59	5.27	3.03	4.95	2.28	2.11	4.55	2.56	39.06
1858	3.45	2.28	3.85	5.68	9.49	6.18	6.56	2.16	3.03	5.91	4.10	7.26	59.95
1859	2.29	4.98	5.67	5.40	4.69	6.83	4.84	2.28	4.08	1.37	4.80	4.05	51.28
1860	1.80	2.60	0.91	3.54	3.19	6.05	2.97	2.96	4.11	1.52	1.63	2.08	33.36
1861	1.16	2.01	7.38	3.18	4.39	4.96	2.04	3.44	4.14	2.85	1.39	1.09	38.03
1862	4.01	0.80	4.11	4.82	2.51	2.85	3.61	1.32	6.27	3.73	3.59	6.38	44.00
1863	4.11	3.99	3.02	1.55	2.68	3.16	2.51	6.93	1.56	4.76	2.15	4.03	40.45
1864	2.74	0.82	1.71	5.58	3.90	0.41	3.60	4.91	2.82	3.15	5.25	2.72	37.61
1865	0.87	3.75	8.61	3.31	5.66	5.21	7.94	1.97	2.60	3.33	0.00	3.63	46.88
1866	4.16	2.24	2.80	1.56	2.24	5.59	3.68	3.71	10.53	2.01	1.37	1.87	41.76
1867	2.28	4.81	2.37	0.53	8.26	5.64	3.71	2.29	0.17	1.31	2.74	3.65	37.76
1868	1.71	0.55	7.66	7.08	3.96	1.58	2.03	8.53	5.25	2.11	2.04	3.09	45.59
1869	2.02	2.49	4.24	7.76	4.35	6.33	4.30	4.10	3.00	3.21	6.59	3.48	51.87
1870	3.58	0.82	3.03	2.45	2.87	2.84	3.95	5.83	1.22	3.43	1.87	2.68	34.57
1871	2.92	4.06	2.39	0.70	4.53	2.56	2.57	2.95	1.08	2.29	2.20	1.76	30.01
1872	0.85	1.43	2.17	3.49	5.37	3.69	7.05	1.82	2.54	0.78	1.26	1.70	32.15
1873	3.62	2.06	3.21	5.59	5.47	4.84	6.18	1.19	3.31	3.19	1.52	7.35	47.58
1874	3.17	4.13	5.33	4.77	3.65	2.70	5.96	7.25	1.90	1.65	3.06	2.88	46.45
1875	0.92	3.50	4.29	1.97	6.89	10.84	12.40	2.78	1.87	1.52	1.80	2.51	51.29
1876	7.97	2.99	5.95	3.23	4.91	5.36	4.69	4.28	4.29	1.73	2.28	0.81	48.49
1877	1.47	1.04	3.28	3.82	4.76	10.05	2.64	3.56	2.58	4.76	3.68	3.17	44.81
1878	3.18	2.70	2.30	5.77	5.22	2.80	5.21	3.83	2.26	3.34	1.84	4.89	43.34
1879	3.37	1.44	3.51	2.46	1.53	2.62	2.14	3.87	1.17	1.79	4.65	3.02	31.57
1880	4.17	2.43	2.61	2.91	4.42	3.23	3.84	3.02	5.40	2.65	2.24	2.15	39.07
1881	0.49	3.00	2.48	2.47	2.84	5.12	2.13	0.31	3.14	7.21	6.74	1.40	37.33
1882	3.10	7.05	3.90	3.03	4.63	5.86	3.52	3.92	3.04	2.65	3.44	2.67	46.81
1883	1.58	7.87	3.18	3.64	4.53	5.90	5.77	2.91	0.10	8.11	5.62	2.79	52.00
1884	1.81	5.66	3.23	3.92	5.29	5.71	3.04	2.12	5.11	2.49	2.37	7.06	47.81
1885	2.95	1.29	0.50	4.04	3.20	5.37	2.55	3.76	7.52	4.42	2.84	2.97	41.41
1886	3.43	1.84	3.18	4.22	4.18	5.93	1.58	3.37	4.73	0.56	5.14	2.74	40.90
1887	1.20	4.53	4.80	4.19	4.17	2.42	2.80	1.18	2.90	1.09	5.16	3.69	38.13
1888	2.44	2.22	4.55	1.79	3.28	5.79	2.78	7.25	1.16	2.60	4.82	2.64	41.32
1889	2.89	2.59	1.75	1.50	4.62	6.18	4.45	2.05	4.32	2.06	5.34	1.99	39.74
1890	8.42	4.61	5.95	4.92	3.60	2.91	2.12	3.95	4.32	1.31	2.63	1.63	46.37
1891	1.95	4.50	3.15	2.34	2.32	4.53	0.90	4.78	1.13	1.28	5.99	1.94	34.81
1892	1.94	4.06	1.80	8.26	6.66	3.54	3.33	3.06	1.49	1.44	4.22	1.54	41.34
1893	1.07	3.43	3.65	9.74	4.68	4.43	1.84	1.55	3.74	2.56	2.28	1.44	40.41
1894	2.29	3.09	2.86	3.12	4.44	1.51	2.06	2.23	3.52	1.61	0.79	3.20	30.72
1895	3.29	0.64	2.16	2.13	2.72	3.30	6.22	2.37	2.54	0.49	4.56	4.11	34.53
1896	1.48	2.29	3.25	1.90	7.64	4.95	5.53	1.96	4.90	2.01	4.07	0.47	40.45
1897	3.97	3.24	10.19	5.33	2.26	4.56	3.58	0.63	0.57	0.61	5.83	3.65	44.42
1898	4.94	1.98	10.99	4.28	6.33	4.78	5.12	3.86	4.15	4.22	2.26	1.74	54.65
1899	3.53	2.93	3.70	1.76	4.02	3.62	4.26	2.61	1.34	3.69	2.08	2.72	36.26
1900	1.20	3.77	2.22	1.63	4.77	7.29	4.35	1.32	3.85	1.90	3.61	1.68	37.59
1901	1.15	2.18	3:80	2.76	2.09	3.20	1.41	2.36	1.40	2.88	1.65	4.56	29.44
1902	1.58	0.98	3.75	2.14	3.20	5.22	2.31	3.93	2.79	1.48	3.78	4.42	35.53
1903	2.03	3.82	3.78	3.99	2.23	3.40	2.86	4.09	1.66	2.98	1.25	2.16	34.25
1904	3.67	2.18	9.69	3.38	3.48	4.13	4.14	3.97	5.95	0.68	0.69	2.62	44.58
1905	2.49	1.55	2.79	4.26	4.05	2.49	6.92	3.15	3.48	6.47	2.24	2.90	42.79
1906	4.64	2.50	5.15	1.85	1.58	2.82	2.11	4.29	5.66	2.00	5.57	3.88	42.05
1907	7.67	0.85	3.55	3.43	4.95	5.12	3.89	5.94	1.25	2.72	3.29	3.68	46.34
1908	2.02	5.99	4.20	5.56	7.79	2.16	3.69	1.94	0.97	0.11	3.21	1.05	38.69
1909	3.82	5.22	3.96	5.85	4.03	4.78	5.74	0.78	4.13	3.00	4.10	3.09	48.00
1910	2.63	3.69	0.11	3.58	3.90	2.96	6.22	2.81	6.21	6.72	1.01	1.77	41.61
1911	1.61	2.59	2.04	6.81	1.44	3.42	1.38	3.20	7.77	3.01	2.91	2.56	38.74
1912	1.96	3.02	5.02	5.99	4.22	4.76	5.66	4.46	3.62	1.75	1.84	0.86	43.16
1913	8.05	1.20	9.17	3.15	1.77	2.55	2.20	2.00	3.86	4.46	4.31	1.61	44.33
1914	2.40	4.11	2.53	2.63	0.48	1.51	1.44	5.43	4.55	4.40	0.98	3.06	33.52
1915	3.99	2.30	0.89	1.03	7.59	6.46	4.31	9.20	2.05	0.78	2.92	4.94	46.46
1916	8.83	1.53	1.85	1.58	3.59	5.30	3.04	8.10	2.44	2.19	1.90	3.18	43.53

PRECIPITATION FOR EXTREME SOUTHERN DISTRICT BY STATIONS

CAIRO, ALEXANDER COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1871	....	....	....	....	.....	....	5.97	2.22	2.34	3.81	2.93	4.25	.....
1872	1.44	2.26	2.02	4.52	5.00	1.79	3.45	0.19	2.56	1.16	0.57	1.56	26.52
1873	5.03	6.68	3.27	5.54	5.07	4.45	1.68	2.48	4.09	5.28	3.04	4.25	50.86
1874	3.11	7.38	6.68	7.57	1.55	2.20	0.52	2.79	3.14	1.54	7.34	3.81	47.63
1875	3.21	2.17	6.73	3.01	3.11	8.41	9.88	3.32	0.16	1.76	7.96	3.21	52.93
1876	15.05	2.34	9.84	2.67	5.84	6.62	3.44	5.24	0.73	2.14	0.96	0.73	55.60
1877	1.93	0.25	3.62	3.87	2.13	4.88	5.63	1.58	3.15	3.12	4.76	4.55	39.47
1878	3.05	1.94	2.97	5.61	4.41	4.61	2.81	3.45	2.99	2.59	3.80	3.53	41.76
1879	2.81	2.03	2.95	3.03	2.79	8.70	1.37	7.05	0.93	3.87	3.25	6.63	45.41
1880	4.56	5.01	4.52	3.25	4.64	2.92	4.34	2.61	4.55	6.96	3.98	2.22	49.56
1881	3.56	4.97	1.33	3.62	2.44	1.81	0.18	0.11	2.74	2.74	4.98	3.70	32.18
1882	6.35	10.14	4.22	4.14	10.22	3.34	5.25	3.46	3.28	2.57	5.96	2.65	61.58
1883	2.74	8.52	2.14	5.64	3.85	6.11	7.95	1.73	0.34	6.97	4.36	2.18	52.53
1884	2.32	5.58	4.20	3.65	4.57	2.95	7.34	2.74	5.02	1.89	2.41	8.99	51.66
1885	3.49	1.48	1.08	1.43	3.21	4.63	0.82	2.40	4.76	2.89	2.79	3.01	31.99
1886	3.82	2.54	2.84	6.64	2.98	4.87	1.01	2.84	2.52	0.45	5.73	1.74	37.98
1887	2.15	4.60	2.18	2.09	1.37	2.34	1.42	1.10	1.67	0.38	3.33	4.12	26.75
1888	2.80	2.51	4.91	3.08	3.58	5.48	3.82	5.45	0.28	3.24	4.85	2.40	41.90
1889	4.61	1.57	1.40	0.97	1.91	8.07	5.15	1.10	3.82	2.81	5.56	0.77	37.74
1890	6.32	7.57	6.14	3.76	4.19	1.45	1.62	5.16	2.29	3.04	6.08	2.91	50.53
1891	3.95	3.20	5.86	1.55	2.48	3.97	2.21	4.77	0.29	0.49	7.30	3.49	39.56
1892	2.01	3.32	2.29	5.28	5.55	3.55	1.73	5.23	0.90	0.74	4.20	3.91	38.71
1893	1.26	3.93	2.09	6.91	6.70	7.59	1.23	1.64	6.83	6.26	2.75	1.60	48.79
1894	2.18	4.77	4.14	2.54	2.79	1.04	1.92	1.68	2.69	1.47	1.42	3.87	30.51
1895	3.77	0.39	2.76	2.75	1.48	4.86	5.97	0.71	1.86	0.50	5.27	3.25	33.57
1896	1.45	1.69	3.97	2.57	10.82	4.73	2.31	1.78	2.95	1.73	4.18	1.18	39.36
1897	3.89	3.95	7.50	6.49	1.12	6.87	2.76	0.89	0.53	0.91	5.50	3.69	44.10
1898	6.26	1.18	9.20	2.13	5.36	1.73	5.67	3.56	6.11	4.64	1.55	1.27	48.66
1899	5.46	2.51	3.59	2.33	5.27	5.74	3.90	1.06	2.25	3.42	3.05	3.84	42.42
1900	2.00	3.20	1.29	1.79	3.98	10.07	3.13	0.27	2.40	1.70	4.63	2.43	36.89
1901	1.52	1.78	3.62	2.70	2.00	0.91	4.57	3.83	1.56	3.40	1.77	4.02	31.68
1902	3.42	1.37	2.12	3.36	2.13	2.47	0.40	3.26	3.29	0.79	3.51	6.95	33.07
1903	2.35	4.19	4.28	1.85	3.52	2.37	4.89	0.81	0.75	1.98	2.07	3.85	32.91
1904	4.05	1.70	4.60	2.98	2.03	3.61	4.20	2.59	1.91	1.20	0.15	2.98	32.00
1905	3.41	1.98	2.84	2.19	4.11	6.00	4.43	3.79	0.69	3.00	3.64	3.40	39.48
1906	6.17	1.42	6.07	1.29	0.46	2.33	3.86	5.73	4.77	0.44	7.88	6.50	46.92
1907	7.77	3.58	3.39	3.81	6.78	2.95	3.92	2.43	1.14	2.90	4.43	2.48	45.58
1908	2.84	6.98	1.88	6.63	4.90	3.15	1.92	4.28	1.01	0.02	3.32	1.54	38.47
1909	2.54	6.70	7.10	4.85	3.96	1.88	3.13	0.01	5.66	0.74	2.58	3.84	42.99
1910	2.63	3.29	1.39	6.78	2.86	2.05	7.59	2.90	0.93	11.57	0.55	3.39	45.93
1911	1.56	2.66	0.77	5.77	0.22	2.08	1.99	2.82	5.15	1.08	3.30	2.71	30.11
1912	4.13	2.41	5.29	5.91	2.51	4.69	1.90	2.28	2.33	3.64	0.62	1.54	37.25
1913	11.65	2.08	7.23	2.27	0.87	1.07	4.19	1.54	2.22	5.50	3.14	0.84	42.60
1914	1.64	3.85	3.31	2.64	2.66	0.92	0.35	2.52	3.73	2.45	0.64	3.51	28.22
1915	4.85	2.90	0.75	1.01	4.13	2.42	3.51	10.28	4.16	1.20	4.18	6.61	46.00
1916	8.11	0.83	1.65	1.66	3.06	8.00	0.21	2.28	2.07	1.29	1.70	4.46	35.32

COBDEN, UNION COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1875	0.95	2.71	5.88	4.09	7.98	7.11	11.09	2.01	0.38	2.09	5.25	1.51	51.05
1876	13.25	2.48	8.82	4.48	5.01	7.76	4.46	9.41	3.14	1.40	2.02	0.78	63.01
1877	1.80	0.70	3.87	4.75	4.45	7.12	1.64	3.47	5.95	5.33	4.58	4.78	48.44
1878	3.16	1.86	2.28	5.66	5.73	3.91	2.82	3.66	2.35	4.25	3.08	4.88	43.64
1879	4.70	2.10	2.39	1.48	2.65	7.02	4.46	12.51	1.40	5.75	4.93	5.59	54.98
1880	4.58	5.38	4.20	4.67	7.27	4.82	3.78	2.20	3.48	4.54	4.28	3.29	52.49
1881	2.79	5.34	1.99	2.29	2.57	5.35	0.00	0.38	1.91	6.51	6.10	2.17	37.40
1882	4.39	3.17	4.52	4.09	9.77	3.04	3.09	4.19	3.47	2.06	6.04	2.97	55.80
1883	2.25	3.19	3.93	5.75	6.64	8.21	2.86	4.02	0.51	7.21	6.85	5.14	61.56
1884	2.01	5.38	4.05	3.80	4.99	7.44	5.49	2.65	3.33	1.42	2.54	9.57	52.67
1885	4.64	1.28	1.43	2.69	2.24	6.89	2.19	4.13	4.54	3.48	1.80	2.92	38.18
1886	3.18	2.88	4.05	3.45	3.71	3.84	1.16	2.68	4.38	0.74	6.65	3.25	39.82
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1895	....	....	....	....	2.10	....	6.52	2.41	....	....	....	....	.....
1896	[a]1.51	1.55	3.72	2.89	9.30	5.50	3.76	2.24	2.38	2.82	3.75	0.89	39.81
1897	4.47	4.47	12.64	3.31	2.00	4.67	2.99	2.05	1.06	0.77	5.18	5.15	53.71
1898	4.20	1.87	14.16	4.28	5.76	7.83	7.35	4.81	5.21	6.42	1.60	1.69	64.68
1899	5.76	3.52	4.04	4.17	6.06	4.26	4.23	1.42	2.44	4.65	1.91	4.17	46.63
1900	1.70	4.09	2.28	2.70	6.57	9.52	4.52	0.51	2.55	2.20	4.00	2.90	43.54
1901	1.34	2.45	5.73	3.74	1.69	2.57	1.20	5.96	0.77	1.97	1.28	5.68	34.38
1902	1.52	2.58	4.22	3.04	3.13	2.78	0.82	4.45	3.42	0.84	4.92	6.36	38.03
1903	2.26	4.76	5.87	3.54	3.16	2.25	3.22	1.85	1.31	3.59	2.22	2.82	36.85
1904	4.05	2.90	6.75	4.28	2.54	5.84	2.83	4.78	9.11	0.90	0.32	2.55	46.30
1905	3.45	2.10	3.08	4.83	4.34	2.10	9.55	2.85	2.94	6.46	2.24	3.50	47.39
1906	6.45	2.36	6.70	1.17	0.67	4.77	3.80	5.07	8.72	1.67	7.75	5.50	54.63
1907	5.82	1.56	2.95	3.11	5.44	2.77	4.18	5.41	0.79	4.22	5.17	3.10	44.52
1908	3.86	3.06	4.60	3.10	5.16	1.70	3.37	3.75	1.92	0.00	4.90	1.07	46.49
1909	2.25	3.26	5.39	9.08	4.33	1.75	10.93	1.39	9.17	0.86	4.31	3.14	60.86
1910	2.43	3.53	0.10	6.19	3.66	4.29	10.82	1.89	2.10	11.48	0.26	2.60	49.30
1911	0.65	3.27	2.22	12.07	1.31	3.59	1.60	6.52	6.13	2.11	4.34	2.96	46.77
1912	2.90	1.43	3.37	6.85	3.64	[a]4.70	3.71	3.18	4.83	2.28	2.65	0.79	40.33
1913	3.18	0.85	7.94	3.19	1.91	0.90	3.77	1.45	4.81	6.97	3.47	1.47	44.86
1914	2.43	4.68	[a]2.97	3.47	1.21	2.05	0.54	4.06	3.16	3.61	1.01	3.67	32.86
1915	4.46	2.49	0.87	0.73	5.07	3.58	3.80	8.81	3.38	0.65	2.52	7.67	43.98

Values from 1875 to 1886, inclusive, and the years 1895, 1914 April to December, inclusive, and 1915, are for Anna.

Values for 1896 to 1908, inclusive, are for Cobden. The stations are 5 miles apart.

[a]Interpolated from surrounding stations.

GOLCONDA, POPE COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1866	0.50	1.20	5.88	2.05	3.33	....	3.32	1.67	7.83	0.87	3.20	3.48	.....
1867	1.90	6.20	4.50	0.70	6.00	1.80	4.40	1.10	0.60	0.90	3.20	1.60	32.90
1868	2.20	0.60	4.10	4.20	3.20	1.30	2.10	2.60	4.70	1.10	1.04	3.30	30.44
1869	1.40	1.20	9.40	4.20	2.20	4.00	2.00	1.00	0.80	0.60	1.10	2.76	30.66
1870	4.50	7.50	4.60	3.80	2.10	3.70	1.40	2.50	1.60	....	....	....	.....
*	*	*	*	*	*	*	*	*	*	*	*	*	*
1878	....	....	....	....	....	....	5.66	1.12	2.96	3.74	4.80	4.78	.....
1879	2.48	2.39	3.15	4.08	1.83	5.95	3.99	11.31	1.65	5.11	4.48	3.61	55.03
1880	5.67	5.51	4.27	3.74	7.50	3.57	6.07	2.65	4.53	6.71	4.37	1.67	56.26
1881	2.80	5.85	2.05	3.91	3.50	4.21	0.61	0.17	4.30	3.69	5.88	4.17	41.09
1882	6.05	10.19	4.72	3.85	10.24	4.00	5.90	11.58	3.88	2.81	5.64	2.43	71.24
1883	3.83	6.84	1.57	6.98	7.18	6.15	4.13	1.27	0.71	6.67	3.66	3.66	57.10
1884	2.12	6.61	4.04	4.95	4.74	7.52	5.49	0.49	5.02	3.46	2.07	3.15	54.66
1885	4.82	1.48	1.01	2.86	2.76	8.82	2.18	4.86	5.78	4.00	2.67	3.24	44.48

GOLCONDA, POPE COUNTY—*Concluded*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1886	3.05	3.01	3.19	4.42	4.05	3.81	1.85	3.89	2.69	0.87	4.97	1.82	36.62
1887	2.14	5.32	2.39	2.89	2.00	2.66	1.11	1.71	5.19	0.64	4.02	3.67	33.74
1888	3.75	1.14	6.59	2.36	2.99	7.00	1.65	4.48	0.72	2.58	4.98	2.14	40.38
1889	4.54	1.15	1.58	0.95	3.38	7.27	5.27	1.57	4.78	1.58	6.58	2.53	41.18
1890	7.35	7.47	9.21	4.79	4.70	2.17	0.83	2.58	4.91	2.90	7.35	1.37	55.63
1891	4.58	3.50	6.62	1.64	3.05	4.84	1.85	6.83	0.38	0.75	7.94	3.84	45.82
1892	1.07	2.99	2.61	5.57	7.24	2.68	4.10	3.94	....	2.05	3.88	1.58	.....
1893	2.04	4.11	2.43	8.82	4.92	3.78	3.04	2.50	2.62	4.63	3.32	2.45	44.66
1894	3.08	4.60	3.54	3.73	3.07	1.77	1.69	2.98	1.80	2.02	1.39	5.41	35.08
1895	3.79	0.38	3.16	2.71	†1.56	†4.44	9.08	1.18	4.04	0.77	7.20	3.46	41.67
1896	1.63	1.64	1.36	....	....	....	....	1.65	3.01	2.79	4.88	1.29	.....
1897	4.49	5.13	11.44	7.65	1.70	3.58	3.84	1.01	0.20	1.29	4.23	3.38	47.94
1898	7.08	1.25	8.93	4.03	5.17	2.33	6.00	1.56	7.68	3.90	2.31	1.84	52.03
1899	6.78	2.97	6.12	3.39	6.20	3.32	4.19	3.47	2.38	3.62	2.14	5.27	49.80
1900	2.17	4.17	1.76	2.62	5.97	10.14	2.73	1.73	2.68	1.41	6.52	2.05	43.95
1901	1.66	1.54	4.10	3.98	1.51	0.91	1.96	3.54	0.70	5.45	1.94	4.33	31.62
1902	3.56	1.80	2.82	3.50	3.33	2.16	1.66	4.20	2.83	1.70	4.96	7.16	39.68
1903	2.63	5.22	5.90	2.65	3.34	1.60	2.76	2.35	1.94	2.83	1.81	3.71	36.74
1904	4.87	2.67	8.47	4.01	2.70	4.01	3.82	3.35	6.49	1.47	0.32	3.58	45.76
1905	3.71	2.03	3.34	4.12	6.93	2.04	6.17	4.30	3.44	7.18	4.34	4.53	52.13
1906	6.81	2.13	7.68	1.90	1.99	3.16	2.74	5.10	4.11	2.12	7.68	8.89	54.31
1907	8.90	2.05	4.04	3.84	7.07	4.82	3.70	6.38	2.09	2.68	4.78	4.12	54.47
1908	3.58	10.31	3.22	6.39	4.92	4.85	3.51	1.93	1.36	0.11	4.16	1.54	45.88
1909	2.78	9.94	5.89	7.05	4.23	3.93	4.09	0.08	5.15	1.39	4.58	5.23	54.34
1910	3.08	3.99	0.30	6.40	3.58	3.67	10.75	3.58	1.69	15.46	1.50	3.52	57.52
1911	2.66	2.62	2.13	8.60	0.99	2.92	4.52	5.40	4.75	2.38	4.00	4.30	45.27
1912	4.57	3.90	6.16	7.04	3.79	5.23	7.14	3.49	2.24	2.32	1.42	2.43	49.73
1913	12.66	2.92	10.77	3.60	1.73	3.07	3.69	2.94	3.96	2.67	4.77	1.83	54.61
1914	1.15	7.23	3.96	3.65	1.96	1.96	1.78	4.54	3.81	3.11	0.72	3.60	37.47
1915	7.45	2.48	1.71	1.82	5.27	4.04	4.86	....	5.49	1.12	4.48	3.60	.....
1916	10.45	2.20	2.34	3.21	4.38	5.18	0.10	....	....	....	....	....	.....

Values from August 1, 1898, to December, 1907, inclusive, are for Raum. All other values are for Golconda. These stations are 7 miles apart.

†Estimated.

NEW BURNSIDE, JOHNSON COUNTY, ILLINOIS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1895	....	....	2.65	2.20	1.98	2.24	5.51	1.26	2.81	0.60	7.08	2.05	.....
1896	1.33	1.20	2.86	3.36	9.44	5.90	4.90	2.54	2.54	1.74	3.14	0.68	39.63
1897	2.70	3.35	10.97	5.82	1.10	4.15	5.81	0.81	1.18	1.20	4.07	2.71	43.87
1898	4.67	1.07	8.51	3.76	7.28	2.77	5.82	3.28	4.33	4.35	0.99	2.24	49.07
1899	5.36	2.63	4.91	4.04	5.87	2.22	4.72	1.42	1.58	5.18	1.86	3.78	43.02
1900	1.84	3.36	1.89	2.08	3.90	9.08	3.43	0.77	2.36	2.74	3.99	1.61	37.05
1901	1.01	2.14	3.72	3.63	1.68	1.34	0.33	2.81	1.00	3.92	1.70	4.85	28.08
1902	2.89	0.77	3.08	3.49	3.20	3.40	2.04	4.33	5.07	*0.78	5.71	6.03	40.79
1903	1.01	4.90	6.21	2.76	3.06	3.13	1.43	2.13	0.89	3.35	1.06	3.19	33.12
1904	4.49	2.92	7.48	5.06	3.11	3.83	5.24	2.33	5.31	1.74	0.51	3.20	45.22
1905	2.61	1.72	2.72	5.25	5.59	2.31	10.39	3.00	2.96	6.44	2.74	3.58	49.31
1906	6.65	2.54	6.68	1.82	1.66	3.11	4.76	4.88	5.43	0.86	8.33	8.31	54.53
1907	9.97	2.11	3.77	2.84	4.85	5.26	4.72	5.56	1.28	3.10	4.30	3.16	50.92
1908	2.84	7.67	3.18	6.52	5.31	1.94	3.74	3.18	1.31	T	4.85	0.62	41.11
1909	2.60	5.35	3.02	5.45	4.01	4.67	3.28	0.15	5.47	0.83	4.09	3.06	41.98
1910	3.06	3.05	0.00	4.80	2.96	2.95	7.38	1.81	1.70	12.48	0.28	2.98	43.35
1911	T	1.84	1.78	11.22	1.78	2.78	3.17	4.09	5.45	2.94	2.14	2.38	39.57
1912	3.16	†1.92	4.66	5.84	3.65	4.70	3.14	4.04	3.50	1.77	1.58	1.39	39.35
1913	9.33	1.16	6.95	3.43	1.64	0.66	5.55	1.09	4.01	6.43	4.19	1.61	46.05
1914	2.06	5.75	3.18	2.49	1.50	1.53	1.97	1.82	3.83	4.20	0.80	3.46	32.59
1915	4.85	2.83	1.26	1.18	6.51	5.15	1.88	9.76	2.82	2.43	3.58	8.86	51.11
1916	10.38	1.69	2.17	3.87	2.12	5.90	1.69	6.22	2.11	2.16	2.02	4.97	45.30

*Value for Halfway, 15 miles distant.

†Estimated from surrounding stations.

PRECIPITATION FOR EXTREME SOUTHERN DISTRICT
AVERAGE OF ALL STATIONS

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1866	0.50	1.20	5.88	2.05	3.33	....	3.32	1.67	7.88	0.87	3.20	3.48	.....
1867	1.90	6.20	4.50	0.70	6.00	1.80	4.40	1.10	0.60	0.90	3.20	1.60	32.90
1868	2.20	0.60	4.10	4.20	3.20	1.30	2.10	2.60	4.70	1.10	1.04	3.30	30.44
1869	1.40	1.20	9.40	4.20	2.20	4.00	2.00	1.00	0.80	0.60	1.10	2.76	30.66
1870	4.50	7.50	4.60	3.80	2.10	3.70	1.40	2.50	1.60	....	....	....	.....
1871	....	....	....	....	....	....	5.97	2.22	2.34	3.81	2.98	4.25	.....
1872	1.44	2.26	2.02	4.52	5.00	1.79	3.45	0.19	2.56	1.16	0.57	1.56	26.52
1873	5.08	6.68	3.27	5.54	5.07	4.45	1.68	2.48	4.09	5.28	3.04	4.25	50.86
1874	3.11	7.88	6.68	7.57	1.55	2.20	0.52	2.79	3.14	1.54	7.34	3.31	47.63
1875	2.08	2.44	6.31	3.55	5.55	7.76	10.49	2.67	0.27	1.93	6.61	2.36	52.02
1876	14.15	2.41	9.33	3.58	5.43	7.19	3.95	7.83	1.94	1.77	1.49	0.76	59.83
1877	1.87	0.48	3.75	4.31	3.29	6.00	3.64	2.53	4.55	4.23	4.67	4.67	43.99
1878	3.11	1.90	2.68	5.64	5.07	4.26	3.76	2.74	2.77	3.53	3.89	4.33	43.68
1879	3.33	2.17	2.83	2.86	2.42	7.22	3.27	10.29	1.33	4.91	4.22	6.94	51.79
1880	4.94	5.30	4.33	3.89	6.47	3.77	4.73	2.49	4.19	6.07	4.21	2.39	52.78
1881	3.05	5.39	1.79	3.27	2.34	3.79	0.26	0.22	2.98	4.31	5.64	3.35	36.39
1882	5.60	9.50	4.49	4.08	10.08	3.46	4.75	6.41	3.53	2.48	5.83	2.68	62.89
1883	2.77	7.85	2.55	6.12	5.87	6.82	4.98	2.34	0.52	6.95	6.62	3.66	57.05
1884	2.15	5.86	4.10	4.13	4.77	5.97	6.11	1.96	4.46	2.26	2.34	8.90	53.01
1885	4.32	1.40	1.17	2.33	2.74	6.78	1.73	3.80	5.03	3.44	2.42	3.06	38.22
1886	3.35	2.63	3.36	4.84	3.58	4.17	1.17	3.12	3.18	0.52	5.78	2.27	37.97
1887	2.15	4.96	2.29	2.49	1.69	2.50	1.27	1.41	3.48	0.51	3.63	3.89	30.27
1888	3.28	1.83	5.75	2.72	3.29	6.24	2.49	4.97	0.50	2.91	4.92	2.27	41.17
1889	4.58	1.36	1.49	0.96	2.65	7.67	5.21	1.34	4.30	2.20	6.07	1.65	39.48
1890	6.84	7.52	7.68	4.28	4.45	1.81	1.23	3.87	3.60	2.97	6.72	2.14	53.11
1891	4.27	3.35	6.24	1.60	2.77	4.41	2.03	5.55	0.34	0.62	7.62	3.67	42.47
1892	1.54	3.16	2.45	5.43	6.40	3.12	2.92	4.59	0.90	1.40	4.04	2.75	38.70
1893	1.65	4.02	2.26	7.87	5.81	5.69	2.14	2.07	4.73	5.45	3.04	2.03	46.76
1894	2.63	4.69	3.84	3.14	2.93	1.41	1.81	2.33	2.25	1.75	1.41	4.64	32.83
1895	3.78	0.39	2.86	2.55	1.78	3.85	6.76	1.38	2.90	0.62	6.50	2.92	36.29
1896	1.48	1.52	2.98	2.94	9.85	5.38	3.66	2.05	2.72	2.15	3.86	1.01	39.60
1897	3.89	4.23	10.64	7.07	1.48	4.82	3.85	1.19	0.74	1.04	4.73	3.73	47.41
1898	5.54	1.22	10.20	3.55	5.89	3.67	6.21	3.30	5.83	4.83	1.61	1.76	53.61
1899	5.84	2.91	4.67	3.48	5.73	3.89	4.26	1.84	2.14	4.22	2.24	4.27	45.49
1900	1.93	3.71	1.81	2.80	5.11	9.70	3.45	0.82	2.50	2.01	4.79	2.25	40.88
1901	1.33	1.98	4.29	3.51	1.71	1.48	2.02	4.04	1.01	3.69	1.67	4.72	31.45
1902	2.85	1.62	3.06	3.35	2.95	2.70	1.23	4.06	3.65	1.03	4.78	6.63	37.91
1903	2.06	4.77	5.57	2.70	3.27	2.34	3.08	1.79	1.23	2.94	1.79	3.39	34.93
1904	4.37	2.55	6.88	4.08	2.60	4.32	4.02	3.25	5.71	1.33	0.33	3.03	42.47
1905	3.30	1.96	2.98	4.10	5.24	3.11	7.64	3.49	2.51	5.77	3.24	3.75	47.09
1906	6.52	2.11	6.78	1.42	1.20	3.34	3.79	5.20	5.76	1.27	7.91	7.30	52.60
1907	8.12	2.33	3.69	3.40	6.04	3.95	4.13	4.97	1.33	3.23	4.67	3.22	49.08
1908	3.28	8.26	3.22	6.91	5.07	2.91	3.14	3.27	1.40	0.03	4.31	1.19	42.99
1909	2.54	7.56	5.35	6.61	4.13	3.06	5.36	0.41	6.36	0.96	3.89	3.82	50.05
1910	2.80	3.47	0.45	6.04	3.27	3.24	9.14	2.55	1.61	12.74	0.64	3.11	49.06
1911	1.22	2.60	1.73	9.42	1.08	2.84	2.82	4.71	5.37	2.13	3.45	3.09	40.46
1912	3.69	2.42	4.87	6.41	3.40	4.83	3.97	3.25	3.23	2.50	1.57	1.54	41.68
1913	10.44	1.75	8.22	3.12	1.54	1.43	4.30	1.76	3.75	5.39	3.89	1.44	47.03
1914	1.82	5.38	3.36	3.06	1.83	1.62	1.16	3.24	3.63	3.34	0.79	3.56	32.79
1915	5.40	2.68	1.15	1.06	5.25	3.80	3.51	9.62	3.95	1.35	3.69	7.94	49.40
1916	9.65	1.57	2.05	2.91	3.17	6.36	0.67	4.25	2.09	1.73	1.86	4.72	41.03

TEMPERATURE RECORDS

(Degrees Fahrenheit)

TEMPERATURE FOR EXTREME NORTHERN DISTRICT

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
1876	26.3	26.4	29.5	46.2	59.5	67.3	73.4	71.4	59.9	51.1	33.8	12.3	46.4
1877	13.7	32.9	24.8	47.0	59.6	66.4	73.6	71.1	65.4	55.9	34.3	39.1	48.6
1878	26.4	33.3	44.6	52.5	55.4	66.1	75.6	71.8	68.5	52.4	33.1	17.9	49.8
1879	15.0	20.5	35.8	48.0	61.3	67.1	74.7	70.8	58.7	62.7	36.0	20.8	47.6
1880	33.6	27.9	33.6	47.6	66.0	70.7	72.9	72.1	60.8	52.6	26.0	17.4	48.4
1881	11.3	18.6	29.1	42.0	67.2	67.2	74.7	73.2	66.5	56.4	34.8	32.4	47.8
1882	22.4	34.1	35.5	46.4	58.0	65.7	67.5	70.4	61.8	54.4	38.0	21.4	47.5
1883	9.2	17.1	28.9	47.6	53.9	66.6	71.3	67.4	58.1	47.5	37.0	25.2	44.1
1884	11.5	21.4	30.2	46.2	58.8	67.3	68.8	67.2	66.6	53.2	34.5	20.7	45.5
1885	10.7	9.5	27.3	44.3	55.6	65.7	72.7	65.2	60.7	45.5	36.7	24.1	43.2
1886	13.1	20.7	30.7	48.9	59.4	67.0	73.1	71.5	62.2	53.0	32.4	16.4	45.7
1887	11.4	21.6	30.1	49.0	64.5	71.2	76.3	69.6	60.5	44.5	35.6	22.9	46.4
1888	8.1	18.4	26.6	45.9	53.8	68.8	73.5	68.9	57.3	47.1	37.6	29.0	44.6
1889	24.0	16.9	38.3	48.5	57.8	65.0	72.5	70.4	61.6	46.5	34.7	37.5	47.8
1890	25.1	29.1	27.0	49.3	55.4	72.5	73.7	67.8	59.2	51.5	39.1	26.4	48.0
1891	26.1	24.7	27.9	49.1	56.7	68.1	67.2	68.8	63.3	49.7	30.7	31.9	47.4
1892	15.1	28.4	30.5	44.6	54.3	66.9	72.1	70.5	62.0	52.1	31.2	18.0	45.5
1893	7.6	16.5	31.4	44.6	54.9	69 6	74.1	69.4	62.8	51.4	33.8	22.5	44.9
1894	22.4	19.2	40.5	50.0	58.6	72.0	75.2	72.1	64.9	51.0	32.1	30.8	49.1
1895	12.9	13.2	32.0	51.0	60.7	72.5	72.8	73.5	68.4	45.1	33.9	26.7	46.9
1896	24.8	24.4	30.3	54.1	67.0	68.9	72.8	72.0	59.4	48.2	34.5	29.4	48.8
1897	18.6	25.9	32.3	46.6	57.2	67.0	75.4	68.6	68.9	56.4	34.6	19.8	47.6
1898	23.5	23.4	37.9	46.1	57.7	69 3	73.2	70.1	65.3	48.1	33.7	20.0	47.4
1899	21.5	14.6	28.7	48.7	59.0	69.5	72.6	73.5	62.0	54.1	43.4	24.0	47.6
1900	25.9	15.2	27.8	50.2	61.8	67.7	71.7	76.6	64.7	59.6	34.7	27.6	48.6
1901	22.5	13.5	32.8	48.4	58.8	71.5	80.3	72.0	62.4	53.6	35.1	21.6	47.7
1902	22.4	17.0	38.6	47.1	61.3	64.6	72.3	67.7	59.5	52.7	44.3	22.6	49.1
1903	21.2	21.8	40.2	48.7	61.7	63.1	71.6	68.1	62.2	51.7	33.7	17.1	46.7
1904	12.9	13.7	33.2	42.5	58.3	66.7	70.8	67.5	63.3	52.5	42.2	22.5	45.5
1905	13.6	13.2	38.7	47.6	58.0	68.1	70.2	72.0	66.2	51.1	36.1	26.1	46.7
1906	27.4	23.5	27.5	51.0	59.7	67.2	71.8	74.0	68.1	51.3	37.0	27.4	48.8
1907	22.4	28.4	41.7	40.0	52.0	66.0	72.4	69.3	61.6	48.9	36.7	29.3	47.0
1908	24.5	23.3	36.5	48.4	59.2	66.7	72.4	69.8	66.5	52.2	39.4	26.8	48.8
1909	24.0	28.2	33.4	43.4	56.7	67.4	71.0	73.6	62.9	47.2	44.4	16.5	47.4
1910	18.6	18.2	46.0	50.7	54.1	68.4	75.5	71.9	62.3	55.0	32.0	21.5	47.8
1911	22.1	29.0	37.1	45.2	64.6	72.4	74.1	69.9	64.2	49.3	31.6	30.7	48.0
1912	4.5	16.3	24.3	48.4	60.7	65.5	72.0	68.6	64.2	52.2	39.6	30.1	45.5
1913	23.8	20.5	31.8	49.5	57.8	70.0	73.9	72.8	68.2	50.3	43.9	33.3	49.2
1914	28.4	16.0	34.4	47.8	61.1	68.0	73.9	71.9	65.4	56.1	40.0	18.1	48.4
1915	16.9	30.4	31.8	55.8	58.6	63.6	68.2	64.4	63.9	52.4	40.5	24.6	47.2

TEMPERATURE FOR CENTRAL-NORTHERN DISTRICT

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
1876	31.4	31.8	32.9	48.8	60.4	68.7	74.6	74.8	62.4	49.8	37.9	17.1	49.1
1877	19.1	37.0	28.6	48.3	59.1	67.9	74.5	72.4	66.6	54.9	38.5	42.5	50.8
1878	31.0	36.3	47.4	53.8	55.9	66.1	76.8	74.9	65.6	52.7	43.2	22.8	52.1
1879	16.6	24.4	38.1	47.6	59.9	66.5	75.5	71.0	59.6	58.4	39.6	25.1	48.5
1880	37.7	32.4	40.1	49.1	64.5	71.5	73.4	72.8	61.7	48.4	29.2	21.0	50.1
1881	14.5	21.3	30.2	43.8	64.5	66.8	75.8	75.7	66.7	55.1	37.9	35.7	48.9
1882	26.4	37.0	38.8	48.2	58.6	66.9	69.4	71.4	63.6	55.7	40.2	24.7	49.6
1883	18.2	21.1	32.3	49.7	56.2	67.9	73.8	69.5	60.7	49.8	39.9	28.8	46.8
1884	15.2	25.8	33.9	47.6	58.4	68.9	71.0	69.4	68.8	55.8	40.2	28.9	48.1
1885	13.9	12.8	30.2	46.8	55.5	68.1	75.8	68.3	63.1	48.3	38.7	26.9	45.7
1886	16.4	24.4	34.5	51.7	61.4	69.4	74.9	74.1	65.4	54.7	33.7	19.5	47.5
1887	14.1	26.2	33.0	50.4	62.6	72.1	73.8	70.9	63.5	46.2	36.2	25.2	48.3
1888	12.1	21.4	30.6	47.6	55.8	69.1	74.6	69.8	59.2	48.2	38.9	31.8	46.6
1889	27.2	20.8	39.7	50.1	59.1	66.1	73.0	70.3	62.2	47.5	37.0	39.9	49.4
1890	29.3	32.5	30.1	51.1	57.2	74.1	74.7	69.4	61.3	51.5	41.1	29.5	50.1
1891	28.4	28.0	30.7	51.0	57.2	69.9	68.9	70.2	68.1	51.3	32.8	34.6	49.4
1892	17.4	30.9	33.1	46.7	55.9	69.0	73.5	72.1	63.5	53.5	33.7	22.5	46.8
1893	10.8	20.5	35.0	47.5	57.1	71.4	76.2	70.6	65.5	58.4	35.6	25.9	47.5
1894	26.1	23.0	43.4	52.4	60.2	74.2	75.7	73.4	66.6	52.9	34.5	32.2	51.2
1895	16.4	16.1	34.6	51.9	62.7	73.4	72.8	74.2	68.9	46.1	35.9	28.7	48.5
1896	26.9	26.4	32.7	55.1	67.9	70.0	73.8	72.9	60.6	48.2	36.8	32.2	50.3
1897	21.0	28.2	35.4	47.6	57.8	69.5	76.6	70.3	70.1	57.9	38.0	28.6	49.6
1898	27.0	26.9	40.7	47.3	59.8	71.4	74.5	71.5	67.1	50.3	35.8	23.6	49.6
1899	22.7	17.2	30.8	51.7	61.7	71.4	73.9	74.4	68.2	57.3	44.2	26.4	49.6
1900	28.4	19.2	30.3	51.0	62.6	68.8	73.7	73.1	66.4	60.6	37.7	29.3	50.5
1901	25.9	16.0	36.0	48.5	59.6	72.9	80.8	72.8	64.2	54.3	35.9	22.1	49.3
1902	24.1	17.7	40.2	48.4	64.0	66.4	74.0	69.2	61.2	54.5	46.0	24.7	49.3
1903	23.7	28.8	42.3	50.2	63.4	64.6	73.5	70.3	63.9	53.1	36.1	20.4	48.7
1904	16.1	17.4	35.9	43.9	60.1	67.7	71.6	68.2	64.5	53.2	41.2	25.2	47.2
1905	16.5	15.1	41.2	49.0	60.2	69.8	71.5	73.5	66.8	51.7	38.9	28.8	48.6
1906	29.2	26.3	28.9	52.6	61.7	68.8	72.3	75.2	69.0	51.9	38.1	29.2	50.2
1907	25.9	26.2	43.3	41.9	54.1	66.7	73.7	70.8	63.2	50.4	37.9	30.8	48.7
1908	26.4	25.1	40.4	50.3	60.8	68.6	74.0	71.6	68.7	53.2	40.8	28.5	50.6
1909	26.0	30.8	35.8	46.7	58.1	69.3	71.7	75.5	62.8	48.8	47.1	18.2	49.2
1910	21.7	21.9	48.4	51.8	55.5	69.1	75.9	72.7	64.1	56.3	34.1	23.6	49.6
1911	25.3	30.4	38.7	46.9	66.6	73.7	74.9	71.3	66.4	51.0	33.2	31.9	50.9
1912	8.9	19.6	27.1	50.3	62.8	67.3	74.1	70.5	66.3	53.8	41.2	32.2	47.8
1913	26.9	23.1	33.7	50.7	60.0	71.4	76.4	75.1	64.9	51.7	45.8	34.6	51.3
1914	30.9	17.8	35.7	50.1	63.2	71.2	76.4	73.9	65.0	56.9	42.4	20.7	50.4
1915	19.4	33.3	33.6	57.0	56.4	65.7	70.8	65.7	65.9	54.6	42.6	26.3	49.3

TEMPERATURE FOR CENTRAL DISTRICT

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
1876	34.2	34.9	35.0	52.8	63.2	70.0	76.6	76.2	64.9	52.4	36.9	19.0	51.3
1877	22.2	38.4	32.4	51.2	62.4	71.9	77.4	74.5	69.2	55.9	39.5	45.4	53.4
1878	33.0	38.6	50.1	56.8	59.8	70.1	81.2	77.8	67.3	54.1	43.5	21.8	54.5
1879	20.8	28.8	42.2	51.9	65.2	70.9	80.2	74.6	63.1	62.7	43.4	29.1	52.8
1880	42.5	37.1	40.8	55.2	68.9	73.5	76.7	77.1	64.7	52.6	31.8	25.8	53.9
1881	25.2	34.4	39.5	51.0	62.9	71.4	75.5	75.9	69.3	58.7	42.2	33.9	53.3
1882	29.9	40.8	43.0	54.4	57.8	71.2	72.8	73.0	65.7	58.7	43.1	29.2	53.2
1883	18.2	27.2	36.8	54.1	59.9	69.7	75.4	70.8	62.9	52.3	43.5	32.8	50.3
1884	20.1	31.0	39.4	51.1	63.5	71.6	74.5	72.1	71.6	58.4	42.2	26.9	51.9
1885	19.5	17.9	35.3	51.1	60.6	70.1	78.2	71.8	65.2	51.5	42.5	31.8	49.6
1886	19.6	28.5	39.5	54.4	65.6	71.9	77.4	76.5	68.7	57.1	39.7	23.6	51.9
1887	21.2	32.3	37.6	52.6	67.6	73.5	80.3	74.9	66.5	48.3	39.1	27.2	51.8
1888	18.5	26.8	35.1	52.6	59.4	71.1	77.2	73.3	63.3	50.8	41.3	34.1	50.3
1889	30.9	26.8	42.6	54.9	61.7	68.5	75.0	73.0	63.8	50.5	38.2	44.0	52.5
1890	33.6	35.4	34.8	54.9	61.1	76.9	76.6	71.1	62.5	54.0	44.7	38.6	53.3
1891	32.9	32.6	34.7	55.3	60.7	72.9	71.6	71.8	70.7	53.9	37.1	37.9	52.7
1892	20.7	35.6	36.7	49.8	59.6	73.4	74.6	74.4	66.1	56.2	36.6	27.9	51.0
1893	16.7	25.4	38.9	51.1	60.2	72.8	78.1	73.3	68.9	55.9	39.6	30.6	51.0
1894	30.4	26.8	46.2	54.5	62.0	75.2	76.5	74.8	67.8	55.4	37.7	34.6	53.5
1895	21.3	20.0	39.4	55.4	64.1	75.0	73.9	74.8	70.7	49.3	39.6	32.9	51.4
1896	30.1	31.8	36.8	60.1	70.2	72.2	75.8	74.9	63.6	52.2	41.4	35.9	53.6
1897	24.9	31.9	41.2	51.2	59.7	71.9	77.3	72.4	72.4	61.5	41.4	27.2	52.8
1898	31.7	32.4	44.1	50.6	62.9	74.4	76.2	74.8	70.3	52.9	38.6	27.7	53.2
1899	27.4	19.9	34.7	54.1	64.4	73.8	75.5	76.8	65.7	60.4	47.1	29.4	52.4
1900	32.1	24.8	35.2	53.9	64.6	71.5	75.8	80.4	69.7	62.6	41.9	32.1	53.7
1901	30.6	28.9	40.2	50.4	61.9	75.2	82.6	75.9	67.5	57.2	39.1	25.7	52.5
1902	27.3	20.2	43.3	50.9	68.0	69.5	76.3	71.7	62.6	57.7	48.9	29.1	52.1
1903	26.7	27.5	45.9	53.3	65.6	66.4	76.1	73.1	66.3	55.7	38.3	24.4	51.7
1904	20.3	23.3	40.5	47.3	62.7	69.7	73.3	71.2	67.8	55.7	43.4	30.2	50.4
1905	21.0	19.0	46.9	52.6	63.7	73.7	73.7	75.8	68.5	54.3	42.5	31.9	51.9
1906	32.9	29.1	30.7	56.2	64.8	70.7	74.1	76.6	71.1	54.5	40.6	32.9	52.8
1907	31.9	30.5	48.5	44.3	57.2	68.5	76.1	73.3	66.3	53.5	40.1	34.3	52.0
1908	30.1	29.2	45.5	52.8	63.8	70.5	75.7	74.4	70.4	55.1	44.2	33.5	53.8
1909	29.4	34.6	40.1	51.4	60.7	72.6	73.2	77.5	65.0	51.5	51.1	21.6	52.4
1910	28.0	26.8	52.3	53.3	57.9	70.1	78.9	72.7	66.9	58.2	37.8	27.5	52.5
1911	30.8	35.8	42.2	50.0	68.8	76.7	76.6	73.6	70.0	54.1	36.8	34.8	54.1
1912	15.1	23.7	31.5	54.1	65.7	68.9	76.2	73.3	68.3	56.8	43.2	34.6	50.9
1913	31.0	26.3	38.0	52.7	64.3	74.9	79.4	79.5	67.9	53.6	48.7	37.3	54.5
1914	34.7	21.8	38.9	57.7	66.0	76.8	79.6	76.5	66.9	58.2	45.4	23.9	53.9
1915	24.2	37.5	35.7	59.0	60.8	69.0	73.1	68.0	68.9	57.1	46.3	30.5	52.5

TEMPERATURE FOR CENTRAL-SOUTHERN DISTRICT

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
1876	41.2	40.9	40.5	57.7	67.2	78.3	79.2	77.4	66.8	55.6	40.8	24.9	55.5
1877	31.3	36.4	39.1	54.9	63.6	72.7	78.8	75.8	69.7	59.7	42.3	47.9	55.9
1878	35.8	37.3	54.3	60.9	63.5	73.6	81.7	79.0	69.0	56.6	47.1	27.1	57.1
1879	28.3	33.8	48.4	55.1	68.8	74.4	80.6	74.8	64.9	62.3	46.8	32.3	55.9
1880	45.7	40.6	43.2	57.8	70.2	76.0	76.8	77.6	66.2	54.6	32.0	27.1	55.6
1881	21.7	31.2	39.5	59.0	71.6	74.5	81.0	82.5	75.3	61.0	43.7	40.8	56.8
1882	32.1	43.9	47.1	57.6	59.5	73.4	73.8	74.0	68.3	61.0	44.6	32.3	55.6
1883	28.2	31.3	38.4	55.8	61.8	71.9	76.1	72.8	66.9	55.5	49.6	39.5	53.6
1884	23.7	34.2	41.7	52.6	68.5	72.5	77.6	78.3	78.1	61.6	45.0	31.0	54.2
1885	23.5	24.9	39.7	55.6	63.5	72.8	77.2	72.5	67.4	53.7	45.9	38.9	52.9
1886	22.7	38.2	43.4	57.8	67.0	72.5	78.7	78.8	70.6	59.9	45.5	27.2	54.8
1887	26.2	37.7	41.9	55.7	69.9	74.7	81.8	77.6	69.8	52.9	43.9	32.3	55.4
1888	25.8	32.7	40.3	57.0	62.7	74.1	78.7	73.9	63.7	51.8	42.9	36.4	53.3
1889	34.0	31.0	45.9	55.9	62.9	70.1	76.4	72.8	64.9	52.5	40.7	48.7	54.6
1890	39.8	40.4	38.4	56.0	63.1	77.9	77.5	73.4	64.6	54.9	46.7	34.5	55.6
1891	34.6	35.3	37.6	56.3	61.3	75.7	73.6	73.1	71.3	54.7	41.1	41.3	54.7
1892	24.0	39.3	39.6	53.8	63.2	75.6	76.3	75.2	67.6	57.2	39.7	32.3	53.6
1893	21.5	30.6	42.1	55.9	61.1	73.6	79.3	73.6	70.6	55.3	41.5	35.3	53.4
1894	35.1	30.8	47.9	56.2	64.6	77.0	77.9	77.5	70.3	58.4	40.8	37.3	56.1
1895	25.6	23.8	43.1	58.6	65.9	77.4	76.1	77.7	73.1	51.1	42.9	36.9	54.3
1896	34.1	36.3	39.3	63.3	71.7	78.9	78.2	78.1	67.2	54.6	46.2	38.5	56.8
1897	29.7	36.1	45.8	54.5	61.3	73.5	79.2	75.7	73.7	63.6	45.2	33.2	55.9
1898	36.4	35.9	47.8	52.5	66.3	76.4	77.6	76.5	72.5	55.1	41.5	31.6	55.7
1899	31.5	22.9	40.0	56.0	66.9	75.8	77.1	78.5	68.6	61.5	49.0	32.4	55.0
1900	35.6	29.1	41.1	56.5	66.7	73.4	77.7	81.6	73.3	63.5	45.5	36.2	56.7
1901	35.3	29.6	44.3	51.8	64.0	77.8	84.2	76.9	69.4	53.6	41.8	29.2	54.8
1902	31.5	25.3	46.6	53.6	71.2	73.8	78.7	75.3	65.7	60.2	52.1	33.3	55.6
1903	32.7	33.7	49.3	55.6	67.7	68.7	78.8	75.9	69.3	57.5	41.3	29.2	55.0
1904	26.5	30.1	44.6	49.8	64.4	71.7	75.0	73.5	70.2	57.0	44.9	33.9	53.5
1905	25.1	24.1	50.0	55.4	66.8	75.4	74.9	76.3	70.2	56.2	45.6	34.6	54.5
1906	37.2	31.2	35.1	58.6	66.6	73.2	75.7	77.9	73.0	56.8	43.6	37.4	55.6
1907	38.1	34.9	53.5	47.4	60.4	70.7	78.5	74.7	68.7	55.7	43.3	38.3	55.4
1908	34.4	34.6	50.6	56.1	67.1	78.9	77.9	77.7	73.3	57.5	47.9	38.8	57.6
1909	34.6	40.1	44.4	55.2	63.4	75.4	76.4	80.1	68.9	55.7	55.1	26.9	56.4
1910	32.5	30.5	56.6	55.9	61.5	71.6	77.6	74.8	70.9	60.4	41.5	30.8	55.4
1911	36.6	39.5	46.8	54.2	70.3	77.6	77.7	75.9	74.2	57.8	40.0	38.6	57.4
1912	20.8	27.3	36.7	57.6	67.7	69.9	78.2	75.4	70.5	59.1	45.1	36.8	53.8
1913	36.4	31.5	42.8	55.3	65.9	77.2	80.9	81.5	69.9	56.3	51.1	39.6	57.5
1914	38.4	27.9	41.9	55.6	67.6	79.9	82.3	78.5	69.1	59.6	48.0	29.0	56.5
1915	28.8	40.0	38.4	61.5	64.7	71.9	76.2	70.5	72.0	60.1	49.5	34.9	55.7

TEMPERATURE FOR EXTREME SOUTHERN DISTRICT

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
1876	44.0	42.8	42.7	59.5	68.2	74.5	80.3	78.6	69.4	56.8	43.7	26.4	57.3
1877	33.4	43.5	43.5	57.2	65.4	75.1	78.3	76.5	70.0	61.2	45.5	49.8	58.3
1878	39.2	43.7	57.1	63.2	67.4	73.0	81.7	80.2	69.7	58.7	49.0	32.3	59.6
1879	33.8	37.6	51.6	57.6	70.4	74.1	81.4	75.0	66.2	65.1	51.7	40.8	58.8
1880	50.7	44.8	49.0	61.8	71.7	75.9	78.4	78.2	67.0	57.7	36.8	32.0	58.7
1881	28.2	37.8	45.0	55.2	73.0	77.6	82.2	83.0	75.4	65.4	46.9	45.0	59.5
1882	38.5	49.0	51.9	60.5	63.8	76.2	75.8	75.1	68.9	64.7	48.9	37.6	59.2
1883	32.3	33.8	43.8	59.9	65.2	75.9	77.7	74.8	68.0	60.2	50.0	42.1	57.4
1884	27.9	42.0	47.6	56.2	66.4	73.7	78.2	75.4	74.2	63.3	48.5	36.2	57.5
1885	29.8	31.9	42.5	59.7	65.6	74.5	80.0	76.5	69.3	55.9	48.7	39.0	56.1
1886	25.4	35.1	44.7	58.0	68.7	71.9	78.1	76.8	70.8	59.5	45.3	30.7	55.4
1887	32.6	43.2	47.4	59.9	71.0	75.5	81.5	78.9	71.7	55.7	46.6	36.0	58.3
1888	30.6	36.4	44.1	60.9	65.1	73.2	79.5	75.5	66.0	54.6	46.6	33.3	55.9
1889	37.5	34.8	49.2	59.5	65.6	70.7	77.1	75.0	67.1	56.3	43.4	53.5	57.5
1890	43.9	44.3	42.2	58.9	65.8	79.4	79.8	75.2	66.6	57.7	50.4	38.9	58.6
1891	37.6	41.0	41.7	59.9	63.9	76.8	74.6	74.4	73.0	58.1	44.0	44.7	57.5
1892	28.2	43.3	43.0	57.5	64.9	76.3	76.9	76.5	70.6	60.2	43.1	36.9	56.5
1893	29.9	37.7	48.0	61.1	65.5	75.2	81.7	78.2	72.6	58.8	46.6	40.7	58.0
1894	40.7	36.5	53.3	59.3	66.2	77.6	78.2	79.3	72.7	60.8	45.6	41.2	59.3
1895	31.6	29.1	47.2	60.5	66.9	78.2	77.4	78.6	76.0	54.6	46.9	40.5	57.3
1896	37.1	40.1	43.1	66.4	73.9	75.5	80.6	80.0	69.7	56.5	49.8	41.7	59.5
1897	33.9	40.5	50.1	57.6	64.4	76.0	80.6	78.1	75.7	65.3	48.8	36.9	59.0
1898	41.4	39.8	51.3	54.9	69.2	78.7	79.0	78.6	74.6	56.9	44.9	35.5	58.7
1899	34.8	26.3	43.8	58.7	70.9	77.6	79.1	81.8	70.8	64.1	52.6	35.2	57.9
1900	39.4	33.8	45.6	59.2	69.5	75.3	80.0	83.5	76.9	66.0	48.7	40.5	59.8
1901	39.3	33.1	47.3	54.4	66.5	79.3	85.1	78.1	71.8	61.4	45.5	32.3	57.8
1902	34.6	27.8	48.9	56.7	73.2	75.9	81.1	78.0	68.1	62.5	54.6	36.9	58.2
1903	35.8	36.9	52.6	57.6	69.3	70.3	80.9	78.5	72.3	59.8	44.3	33.1	57.6
1904	32.3	34.5	48.3	52.1	66.4	74.2	76.6	76.0	72.6	59.0	48.0	37.7	56.5
1905	27.4	27.5	52.9	58.2	69.4	76.7	76.3	78.1	72.2	58.5	48.7	36.8	56.9
1906	39.3	34.7	38.1	61.3	67.9	75.2	75.7	78.2	75.1	58.3	46.2	39.4	57.4
1907	41.9	37.5	56.5	50.2	61.9	72.5	80.2	77.6	71.1	58.1	45.6	39.4	57.7
1908	35.6	37.5	53.6	58.7	68.7	75.4	78.8	78.5	74.0	58.9	51.3	41.6	59.4
1909	35.6	41.6	46.2	56.4	64.9	76.4	78.2	80.6	69.5	58.1	56.7	30.1	57.9
1910	35.1	32.9	58.0	57.0	63.3	71.9	78.5	76.1	73.5	61.5	43.8	33.2	57.1
1911	40.4	42.3	49.5	57.0	71.0	78.5	78.4	76.3	76.1	59.9	42.6	41.1	59.4
1912	24.8	31.1	40.4	58.9	67.9	70.5	78.9	76.3	71.9	60.9	47.0	38.2	55.6
1913	39.5	35.1	45.6	56.5	67.5	77.9	80.6	83.1	70.9	57.7	53.6	40.9	58.9
1914	40.7	32.7	43.7	56.7	68.0	80.8	82.2	78.2	70.3	60.6	49.5	31.8	57.9
1915	32.6	41.5	39.3	62.3	67.0	73.2	77.2	71.4	72.7	62.0	51.8	37.8	57.4

TEMPERATURE FOR CENTRAL-SOUTHERN DISTRICT

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
1876	41.2	40.9	40.5	57.7	67.2	73.8	79.2	77.4	66.8	55.6	40.8	24.9	55.5
1877	31.3	36.4	39.1	54.9	63.6	72.7	78.3	75.8	69.7	59.7	42.3	47.9	55.9
1878	35.8	37.3	54.3	60.9	63.5	73.6	81.7	79.0	69.0	56.6	47.1	27.1	57.1
1879	28.3	33.8	48.4	55.1	68.8	74.4	80.6	74.8	64.9	62.3	46.8	32.3	55.9
1880	45.7	40.6	43.2	57.8	70.2	76.0	76.8	77.6	66.2	54.6	32.0	27.1	55.6
1881	21.7	31.2	39.5	59.0	71.6	74.5	81.0	82.5	75.8	61.0	43.7	40.8	56.8
1882	32.1	43.9	47.1	57.6	59.5	73.4	78.8	74.0	68.8	61.0	44.6	32.8	55.6
1883	23.2	31.3	38.4	55.8	61.8	71.9	76.1	72.8	66.9	55.5	49.6	39.5	53.6
1884	23.7	34.2	41.7	52.6	63.5	72.5	77.6	73.3	73.1	61.6	45.0	31.0	54.2
1885	23.5	24.9	39.7	55.6	63.5	72.8	77.2	72.5	67.4	53.7	45.9	38.9	52.9
1886	22.7	33.2	43.4	57.8	67.0	72.5	78.7	78.3	70.6	59.9	45.5	27.2	54.8
1887	26.2	37.7	41.9	55.7	69.9	74.7	81.8	77.6	69.8	52.9	43.9	32.3	55.4
1888	25.8	32.7	40.3	57.0	62.7	74.1	78.7	73.9	63.7	51.8	42.9	36.4	53.3
1889	34.0	31.0	45.9	55.9	62.9	70.1	76.4	72.8	64.9	52.5	40.7	48.7	54.6
1890	39.8	40.4	38.4	56.0	63.1	77.9	77.5	73.4	64.6	54.9	46.7	34.5	55.6
1891	34.6	35.3	37.6	56.3	61.3	75.7	73.6	73.1	71.3	54.7	41.1	41.3	54.7
1892	24.0	39.3	39.6	53.3	63.2	75.6	76.3	75.2	67.6	57.2	39.7	32.3	53.6
1893	21.5	30.6	42.1	55.9	61.1	73.6	79.3	73.6	70.6	55.3	41.5	35.3	53.4
1894	35.1	30.8	47.9	56.2	64.6	77.0	77.9	77.5	70.3	58.4	40.8	37.3	56.1
1895	25.6	23.8	43.1	58.6	65.9	77.4	76.1	77.7	73.1	51.1	42.9	36.9	54.3
1896	34.1	36.8	39.3	63.3	71.7	73.9	78.2	78.1	67.2	54.6	46.2	38.5	56.8
1897	29.7	36.1	45.8	54.5	61.8	73.5	79.2	75.7	73.7	63.6	45.2	33.2	55.9
1898	36.4	35.9	47.8	52.5	66.3	76.4	77.6	76.5	72.5	55.1	41.5	31.6	55.7
1899	31.5	22.9	40.0	56.0	66.9	75.8	77.1	78.5	68.6	61.5	49.0	32.4	55.0
1900	35.6	29.1	41.1	56.5	66.7	73.4	77.7	81.6	73.3	63.5	45.5	36.2	56.7
1901	35.3	29.6	44.3	51.8	64.0	77.8	84.2	76.9	69.4	53.6	41.8	29.2	54.8
1902	31.5	25.8	46.6	53.6	71.2	73.8	78.7	75.8	65.7	60.2	52.1	33.3	55.6
1903	32.7	33.7	49.3	55.6	67.7	68.7	78.8	75.9	69.3	57.5	41.3	29.2	55.0
1904	26.5	30.1	44.6	49.8	64.4	71.7	75.0	73.5	70.2	57.0	44.9	33.9	53.5
1905	25.1	24.1	50.0	55.4	66.8	75.4	74.9	76.3	70.2	56.2	45.6	34.6	54.5
1906	37.2	31.2	35.1	58.6	66.6	73.2	75.7	77.9	73.0	56.8	43.6	37.4	55.6
1907	38.1	34.9	53.5	47.4	60.4	70.7	78.5	74.7	68.7	55.7	43.3	38.8	55.4
1908	34.4	34.6	50.6	56.1	67.1	73.9	77.9	77.7	73.8	57.5	47.9	38.8	57.6
1909	34.6	40.1	44.4	55.2	63.4	75.4	76.4	80.1	68.9	55.7	55.1	26.9	56.4
1910	32.5	30.5	56.6	55.9	61.5	71.6	77.6	74.8	70.9	60.4	41.5	30.8	55.4
1911	36.6	39.5	46.8	54.2	70.8	77.6	77.7	75.9	74.2	57.8	40.0	38.6	57.4
1912	20.8	27.3	36.7	57.6	67.7	69.9	78.2	75.4	70.5	59.1	45.1	36.8	53.8
1913	36.4	31.5	42.8	55.3	65.9	77.2	80.9	81.5	69.9	56.3	51.1	39.6	57.5
1914	38.4	27.9	41.9	55.6	67.6	79.9	82.3	78.5	69.1	59.6	48.0	29.0	56.5
1915	28.8	40.0	38.4	61.5	64.7	71.9	76.2	70.5	72.0	60.1	49.5	34.9	55.7

TEMPERATURE FOR EXTREME SOUTHERN DISTRICT

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
1876	44.0	42.8	42.7	59.5	68.2	74.5	80.3	78.6	69.4	56.8	43.7	26.4	57.3
1877	33.4	43.5	43.5	57.2	65.4	75.1	78.3	76.5	70.0	61.2	45.5	49.8	58.3
1878	39.2	43.7	57.1	63.2	67.4	73.0	81.7	80.2	69.7	58.7	49.0	32.8	59.6
1879	33.8	37.6	51.6	57.6	70.4	74.1	81.4	75.0	66.2	65.1	51.7	40.8	58.8
1880	50.7	44.8	49.0	61.8	71.7	75.9	78.4	78.2	67.0	57.7	36.8	32.0	58.7
1881	28.2	37.8	45.0	55.2	73.0	77.6	82.2	83.0	75.4	65.4	46.9	45.0	59.5
1882	38.5	49.0	51.9	60.5	63.8	76.2	75.8	75.1	68.9	64.7	48.9	37.6	59.2
1883	32.3	38.8	48.8	59.9	65.2	75.9	77.7	74.8	68.0	60.2	50.0	42.1	57.4
1884	27.9	42.0	47.6	56.2	66.4	78.7	78.2	75.4	74.2	63.3	48.5	36.2	57.5
1885	29.8	31.9	42.5	59.7	65.6	74.5	80.0	76.5	69.3	55.9	48.7	39.0	56.1
1886	25.4	35.1	44.7	58.0	68.7	71.9	78.1	76.8	70.8	59.5	45.3	30.7	55.4
1887	32.6	43.2	47.4	59.9	71.0	75.5	81.5	78.9	71.7	55.7	46.6	36.0	58.3
1888	30.6	36.4	44.1	60.9	65.1	78.2	79.5	75.5	66.0	54.6	46.6	38.3	55.9
1889	37.5	34.8	49.2	59.5	65.6	70.7	77.1	75.0	67.1	56.3	43.4	53.5	57.5
1890	43.9	44.3	42.2	58.9	65.8	79.4	79.8	75.2	66.6	57.7	50.4	38.9	58.6
1891	37.6	41.0	41.7	59.9	63.9	76.8	74.6	74.4	73.0	58.1	44.0	44.7	57.5
1892	28.2	43.3	43.0	57.5	64.9	76.3	76.9	76.5	70.6	60.2	43.1	36.9	56.5
1893	29.9	37.7	48.0	61.1	65.5	75.2	81.7	78.2	72.6	58.8	46.6	40.7	58.0
1894	40.7	36.5	53.3	59.3	66.2	77.6	78.2	79.3	72.7	60.8	45.6	41.2	59.3
1895	31.6	29.1	47.2	60.5	66.9	78.2	77.4	78.6	76.0	54.6	46.9	40.5	57.3
1896	37.1	40.1	43.1	66.4	73.9	75.5	80.6	80.0	69.7	56.5	49.8	41.7	59.5
1897	33.9	40.5	50.1	57.6	64.4	76.0	80.6	78.1	75.7	65.3	48.8	36.9	59.0
1898	41.4	39.8	51.3	54.9	69.2	78.7	79.0	78.6	74.6	56.9	44.9	35.5	58.7
1899	34.8	26.3	43.8	58.7	70.9	77.6	79.1	81.8	70.8	64.1	52.6	35.2	57.9
1900	39.4	33.8	45.6	59.2	69.5	75.3	80.0	83.5	76.9	66.0	48.7	40.5	59.8
1901	39.3	33.1	47.3	54.4	66.5	79.3	85.1	78.1	71.8	61.4	45.5	32.3	57.8
1902	34.6	27.8	48.9	56.7	73.2	75.9	81.1	78.0	68.1	62.5	54.6	36.9	58.2
1903	35.8	36.9	52.6	57.6	69.3	70.3	80.9	78.5	72.3	59.8	44.3	33.1	57.6
1904	32.3	34.5	48.3	52.1	66.4	74.2	76.6	76.0	72.6	59.0	48.0	37.7	56.5
1905	27.4	27.5	52.9	58.2	69.4	76.7	76.3	78.1	72.2	58.5	48.7	36.8	56.9
1906	39.3	34.7	38.1	61.3	67.9	75.2	75.7	78.2	75.1	58.3	46.2	39.4	57.4
1907	41.9	37.5	56.5	50.2	61.9	72.5	80.2	77.6	71.1	58.1	45.6	39.4	57.7
1908	35.6	37.5	53.6	58.7	68.7	75.4	78.8	78.5	74.0	58.9	51.3	41.6	59.4
1909	35.6	41.6	46.2	56.4	64.9	76.4	78.2	80.6	69.5	58.1	56.7	30.1	57.9
1910	35.1	32.9	58.0	57.0	63.3	71.9	78.5	76.1	73.5	61.5	43.8	33.2	57.1
1911	40.4	42.3	49.5	57.0	71.0	78.5	78.4	76.3	76.1	59.9	42.6	41.1	59.4
1912	24.8	31.1	40.4	58.9	67.9	70.5	78.9	76.3	71.9	60.9	47.0	38.2	55.6
1913	39.5	35.1	45.6	56.5	67.5	77.9	80.6	83.1	70.9	57.7	53.6	40.9	58.9
1914	40.7	32.7	43.7	56.7	68.0	80.8	82.2	78.2	70.3	60.6	49.5	31.8	57.9
1915	32.6	41.5	39.3	62.3	67.0	73.2	77.2	71.4	72.7	62.0	51.8	37.8	57.4

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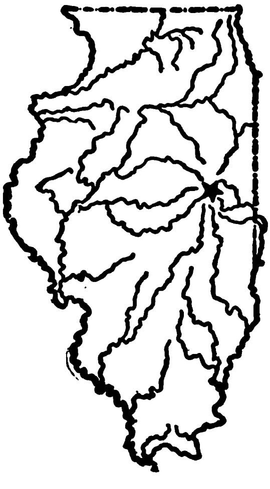
UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

BULLETIN No. 209

FERTILIZING CONSTITUENTS EXCRETED BY TWO-YEAR-OLD STEERS

BY H. S. GRINDLEY, H. W. MUMFORD, A. D. EMMETT,
AND SLEETER BULL



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FERTILIZING CONSTITUENTS EXCRETED BY TWO-YEAR-OLD STEERS

BY H. S. GRINDLEY, H. W. MUMFORD, A. D. EMMETT, AND SLEETER BULL[1]

This bulletin is one of a series[2] reporting the findings of an investigation in regard to the effect of variations in the character and amount of feed consumed upon the nutrition of steers. It gives the results relating to the fertilizing constituents of the excreta, including (1) the amounts of nitrogen, phosphorus, and organic matter excreted, (2) the manner of excretion, i. e., whether via the feces or the urine, and (3) the commercial value of the fertilizing elements of the excreta.

Inasmuch as no bedding was used in this experiment, its fertilizing value is not considered in the general discussion of the results. It should be borne in mind, however, that ordinary bedding, such as straw, does contain considerable fertilizing value which should be added to the commercial value of the excreta proper. For a discussion of the manurial value of bedding the reader is referred to other sources.[3]

THE EXPERIMENT

The Animals.—The animals used were eight two-year-old high-grade Hereford steers, grading as choice feeders and weighing from 800 to 1,000 pounds. These animals were selected from the same herd. From birth to the time of purchase they had been treated very much alike. During a period of about two months preliminary to the experiment they were kept in paved lots with access to open sheds, and during the experiment proper, which lasted from May 27, 1908, to February 10, 1909, a period of thirty-seven weeks, they were kept in digestion and metabolism stalls.

Rations and Feeds.—During the first month of the period preliminary to the experiment the ration consisted of corn silage, clover hay, and alfalfa hay. At the beginning of the second month ground corn was added to the ration, and the feeding of alfalfa was discontinued. Four days later the feeding of corn silage was discontinued.

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[1] The authors take pleasure in acknowledging their great indebtedness to Professors L. D. Hall and H. O. Allison for their generous and helpful cooperation and assistance in the planning and conducting of this investigation.

[2] See Ill. Agr. Exp. Sta. Buls. 172 and 197.

[3] Hopkins: Soil Fertility and Permanent Agriculture, p. 541, *et seq.* Van Slyke: Fertilizers and Crops, p. 301, *et seq.*

During the first twenty-two weeks of the experiment proper the ration consisted of clover hay and ground corn, and during the last fifteen weeks, of clover hay, ground corn, and linseed oil meal. Half an ounce of salt, given daily, was taken very consistently by all of the steers. Water also was given twice daily, and an exact record was kept of the amounts drunk.

To determine the effect of variations in the proportions of roughage to concentrates in the ration, and the effect of the introduction of linseed oil meal into the ration, the experiment was divided into five experimental periods. During the first experimental period the ration consisted of clover hay and ground corn in equal amounts by weight; during the second, of one part of clover hay and three parts of ground corn; during the third, of one part of clover hay and five parts of ground corn; and during the fourth and fifth, of one part of clover hay, four parts of ground corn, and one part of linseed oil meal. Thus the proportion of concentrates was gradually increased up to the third experimental period, and then maintained constant to the end of the experiment. These changes are comparable to the changes often made in the proportions of roughage and concentrates in ordinary feeding practice. The first experimental period was five weeks in length; the second, third, and fourth, each six weeks in length; and the fifth, four weeks in length. The changes in the ration made from one test period to another were effected very gradually in transitional periods one of which immediately followed each experimental period. The first and third transitional periods were two weeks in length; and the second and fourth, three weeks in length.

TABLE 1.—DIVISION OF EXPERIMENT INTO PERIODS, AND RATIOS OF HAY, CORN AND LINSEED MEAL IN RATIONS

Experimental period	Experimental weeks	Number of weeks in period	Ratio of hay to corn to linseed meal
1	1–5	5	1:1:0
2	8–13	6	1:3:0
3	17–22	6	1:5:0
4	25–30	6	1:4:1
5	34–37	4	1:4:1

To determine the effect of variations in the amount of feed consumed, the eight steers were divided into four lots of two animals each, and each lot was given thruout the experiment an amount of feed different from that received by the other lots. The lots were as similar as possible in regard to age, condition, and breeding. One lot was given just enough feed to maintain the weights of the steers about constant; another, as much as the steers would eat readily; another, an amount of feed equal to the maintenance ration plus one-third of the difference between the maintenance and the full-feed rations; and another, an amount equal to the maintenance ration plus two-thirds of the difference between the maintenance and full-feed rations. Beginning with the 31st week, one steer each from the maintenance, the one-third, and the two-thirds feed lots was gradually put on a full-feed ration and continued thus until the end of the experiment.

The average daily gains of the different lots during the thirty-seven weeks of the experiment were as follows: maintenance lot, 0.76 pound; one-third-feed lot, 1.28 pounds; two-thirds-feed lot, 1.76 pounds; and full-feed lot, 2.05 pounds.

Equipment and Methods.—For a detailed description of the equipment and methods used in this investigation, see Bulletin 172 of this station. In this connection, it will be sufficient to state briefly the essentials of the procedure. The feeds were thoroly mixed, analyzed, and weighed out to each steer. The refused feeds, or orts, were also weighed, mixed, and analyzed. From the data so obtained, the quantities of organic matter, nitrogen, and phosphorus consumed by each steer were calculated. The feces were weighed, mixed, and analyzed, and the quantities of organic matter, nitrogen, and phosphorus excreted via the intestines were calculated. The urine was weighed, mixed, and analyzed, and the quantities of nitrogen and phosphorus excreted thru the kidneys were calculated. The details of the methods used in the collection and sampling of the urine are given below since they were not reported in Bulletin 172.

Collection and Sampling of Urine.—The weighing of the urine was done at the end of the experimental day. After the total weight of this twenty-four hour sample was obtained, the urine was stirred thoroly and one-fourth of the total amount was weighed off for the daily sample. The urine sample was transferred to a dry, thymolized bottle, provided with a cork stopper. The acidity or alkalinity of the urine to litmus was ascertained at the time of the sampling each day. The samples of urine and feces were taken to cold storage rooms and kept until the end of the experimental week.

The samples of the urine were composited weekly. In doing this, the seven daily fractions for each steer were transferred to a large pail and stirred thoroly until well mixed. Then two liters of the composite sample was strained thru a 40-mesh sieve into a thymolized bottle. In this way hair or foreign matter that might be present was removed, but the normal sediment passed thru. The alkalinity or acidity of the composite samples, the color of the urines, the comparative amount of sediment, and the specific gravity, with the temperature, were all recorded. The samples were then ready for chemical examination.

Methods of Analysis.—The methods of analysis used in this experiment were essentially the same as the official methods given in the revised edition for 1908 of Bulletin 107 of the Bureau of Chemistry, United States Department of Agriculture. The total carbohydrates were determined by difference. No determinations were made of the crude fiber.

AMOUNTS AND COMPOSITION OF FEEDS CONSUMED

The total amounts of feeds consumed by each animal per period are given in Table 2; the average amounts of feeds consumed daily per steer per period are given in Table 3; and Table 4 shows the average chemical composition of the feeds. For a more complete discussion of the feed consumption and composition, the reader is referred to Bulletin 197 of this station.

TABLE 2.—TOTAL FEED CONSUMED PER PERIOD
(Results expressed in pounds)

Period	Weeks	Ratio of hay to corn to linseed meal	Clover hay	Ground corn	Linseed meal	Clover hay	Ground corn	Linseed meal
			Maintenance Lot					
			Steer 650			Steer 656		
1	1-5	1:1:0	192.6	192.6	....	192.6	192.6	....
2	8-13	1:3:0	95.8	287.3	....	95.6	286.8	....
3	17-22	1:5:0	58.8	294.0	....	58.8	294.0	....
4	25-30	1:4:1	58.2	233.0	58.2	58.2	233.0	58.2
5[3]	34-37	1:4:1	81.7	326.9	81.7	37.0	147.8	37.0
Total[4]	1-37	....	627.4	1791.6	184.7	577.4	1589.5	133.3
			One-Third-Feed Lot					
			Steer 666			Steer 669		
1	1-5	1:1:0	270.0	270.0	....	277.9	277.9	....
2	8-13	1:3:0	153.4	460.3	....	160.0	479.8	....
3	17-22	1:5:0	88.5	442.4	....	96.0	480.2	....
4	25-30	1:4:1	84.0	336.0	84.0	90.7	362.9	90.7
5[3]	34-37	1:4:1	88.6	354.4	88.6	60.5	241.9	60.5
Total[4]	1-37	....	890.7	2537.3	236.3	901.8	2549.9	214.3
			Two-Thirds-Feed Lot					
			Steer 652[1]			Steer 665		
1	1-5	1:1:0	348.9	348.9	....	362.8	362.8	....
2	8-13	1:3:0	210.1	630.4	.....	224.7	674.3	....
3	17-22	1:5:0	119.3	596.4	....	134.4	672.0	....
4	25-30	1:4:1	109.8	439.0	109.8	123.2	492.8	123.2
5[3]	34-37	1:4:1	21.5	86.1	21.5	84.0	336.0	84.0
Total[4]	1-37	.....	1079.6	2981.3	211.1	1221.7	3503.1	294.4
			Full-Feed Lot					
			Steer 663[2]			Steer 661		
1	1-5	1:1:0	408.4	408.4	.....	444.1	444.1	.....
2	8-13	1:3:0	241.3	723.9	.....	283.6	851.0	.....
3	17-22	1:5:0	128.5	642.6	.....	144.8	724.2	.....
4	25-30	1:4:1	118.2	472.8	118.2	155.7	622.7	155.7
5	34-37	1:4:1	.....	.....	.....	105.2	420.8	105.2
Total[4]	1-37	.....	1144.1	3002.2	145.2	1496.6	4252.3	372.3

[1] Removed at end of 34th week. [2] Removed at end of 30th week.

[3] Steers 650, 666, and 652 were on full feed in this period.

[4] Includes feeds for transitional periods.

TABLE 3.—AVERAGE FEED CONSUMED DAILY
(Results expressed in pounds)

Period	Weeks	Ratio of hay to corn to linseed meal	Clover hay	Ground corn	Linseed meal	Clover hay	Ground corn	Linseed meal
			Maintenance Lot					
			Steer 650			Steer 656		
1	1-5	1:1:0	5.50	5.50	....	5.50	5.50	....
2	8-13	1:3:0	2.28	6.84	....	2.28	6.83	....
3	17-22	1:5:0	1.40	7.00	....	1.40	7.00	....
4	25-30	1:4:1	1.39	5.55	1.39	1.39	5.55	1.39
5[3]	34-37	1:4:1	2.92	11.67	2.92	1.32	5.28	1.32
			One-Third-Feed Lot					
			Steer 666			Steer 669		
1	1-5	1:1:0	7.71	7.71	....	7.94	7.94	....
2	8-13	1:3:0	3.65	10.96	....	3.81	11.42	....
3	17-22	1:5:0	2.11	10.53	....	2.29	11.43	....
4	25-30	1:4:1	2.00	8.00	2.00	2.16	8.64	2.16
5[3]	34-37	1:4:1	3.16	12.66	3.16	2.16	8.64	2.16
			Two-Thirds-Feed Lot					
			Steer 652[1]			Steer 665		
1	1-5	1:1:0	9.97	9.97	....	10.37	10.37	....
2	18-13	1:3:0	5.00	15.01	....	5.35	16.06	....
3	17-22	1:5:0	2.84	14.20	....	3.20	16.00	....
4	25-30	1:4:1	2.61	10.45	2.61	2.93	11.73	2.93
5[3]	34-37	1:4:1	3.07	12.29	3.07	3.00	12.00	3 00
			Full-Feed Lot					
			Steer 663[2]			Steer 661		
1	1-5	1:1:0	11.67	11.67	....	12.69	12.69	....
2	8-13	1:3:0	5.75	17.24	....	6.75	20.26	....
3	17-22	1:5:0	3.06	15.30	....	3.45	17.24	....
4	25-30	1:4:1	2.81	11.26	2.81	3.71	14.83	3.71
5	34-37	1:4:1	....	.....	....	3.76	15.03	3.76

[1] Removed at end of 34th week. [2] Removed at end of 30th week.
[3] Steers 650, 666, and 652 were on full feed in this period.

TABLE 4.—AVERAGE COMPOSITION OF FEEDS
(Results expressed in percent of fresh substance)

Feed	Dry substance	Organic matter	Crude protein (N x 6.25)	Total carbohydrates	Fat (ether extract)	Ash	Total nitrogen	Phosphorus
Ground corn..	87.09	85.82	7.69	74.21	3.93	1.27	1.230	0.263
Linseed meal..	90.74	85.32	34.80	43.72	6.79	5.42	5.564	0.869
Clover hay....	88.46	83.07	10.97	69.75	2.36	5.39	1.756	0.153

AMOUNTS AND COMPOSITION OF FECES

As would be expected, the amounts of feces excreted depended roughly upon the amount of the ration consumed and upon the proportion of roughage in the ration (see Tables 5 and 6). However, there was considerable variation in the amounts excreted by the steers of the same lot in the same period.

TABLE 5.—TOTAL FECES EXCRETED PER PERIOD
(Results expressed in pounds)

Period	Weeks	Ratio of hay to corn to linseed meal	Maintenance Lot		One-Third-Feed Lot	
			Steer 650	Steer 656	Steer 666	Steer 669
1	1-5	1:1:0	721.45	623.25	966.05	1284.15
2	8-13	1:3:0	457.02	468.78	848.28	927.66
3	17-22	1:5:0	344.52	372.36	559.32	644.04
4	25-30	1:4:1	284.40	336.96	515.76	581.40
5[5]	34-37	1:4:1	555.36	227.14	757.37	373.49
Total[4]	1-37	....	3066.19	2713.39	4868.95	5155.09
			Two-Thirds-Feed Lot		Full-Feed Lot	
			Steer 652[1]	Steer 665	Steer 663[2]	Steer 661
1	1-5	1:1:0	1599.95	1583.45	1824.25[3]	2156.25
2	8-13	1:3:0	1306.38	1448.76	1469.16	2240.64
3	17-22	1:5:0	823.02	1063.92	918.66	1323.24
4	25-30	1:4:1	802.32	872.88	698.82	1177.74
5[5]	34-37	1:4:1	155.17	603.78	......	802.05
Total[4]	1-37	......	6473.49	7545.01	6469.69	10538.34

[1]Removed at end of 34th week. [2]Removed at end of 30th week.
[3]Weeks 3, 4, and 5 only. [4]Includes transitional periods.
[5]Steers 650, 666, and 652 were on full feed in this period.

TABLE 6.—AVERAGE FECES EXCRETED PER WEEK
(Results expressed in pounds)

Period	Weeks	Ratio of hay to corn to linseed meal	Maintenance Lot		One-Third-Feed Lot	
			Steer 650	Steer 656	Steer 666	Steer 669
1	1-5	1:1:0	144.29	124.65	193.21	256.83
2	8-13	1:3:0	76.17	78.13	141.38	154.61
3	17-22	1:5:0	57.42	62.06	93.22	107.34
4	25-30	1:4:1	47.40	60.66	85.96	96.90
5[5]	34-37	1:4:1	138.84	56.78	189.34	93.37
Average[4]	1-37	....	82.87	73.33	131.59	139.33
			Two-Thirds-Feed Lot		Full-Feed Lot	
			Steer 652[1]	Steer 665	Steer 663[2]	Steer 661
1	1-5	1:1:0	319.99	316.69	364.85[3]	431.25
2	8-13	1:3:0	217.73	241.46	244.86	373.44
3	17-22	1:5:0	137.17	177.32	153.11	220.54
4	25-30	1:4:1	133.72	145.48	116.47	196.29
5[5]	34-37	1:4:1	155.17	150.94	......	200.51
Average[4]	1-37	....	190.40	203.92	231.0	284.82

[1]Removed at end of 34th week. [2]Removed at end of 30th week.
[3]Weeks 3, 4, and 5 only. [4]Includes transitional periods.
[5]Steers 650, 666, and 652 were on full feed in this period.

With respect to the percentages of water and organic matter in the feces, the individual steers of the different lots were quite similar in the same period (see Table 7). In the cases of nitrogen and phosphorus, the variations of the different steers in the same period were greater.

TABLE 7.—CHEMICAL COMPOSITION OF FECES
(Results expressed in percent of fresh substance)

Period	Weeks	Ratio of hay to corn to linseed meal	Water	Organic matter	Nitrogen	Phosphorus	Water	Organic matter	Nitrogen	Phosphorus
			Maintenance Lot							
			Steer 650				Steer 656			
1	1-5	1:1:0	85.32	13.42	0.478	0.110	83.82	14.87	0.488	0.101
2	8-13	1:3:0	83.14	15.40	0.586	0.189	84.77	14.08	0.537	0.101
3	17-22	1:5:0	80.53	17.85	0.643	0.232	82.52	16.31	0.596	0.088
4	25-30	1:4:1	78.66	19.20	0.755	0.339	82.11	16.63	0.620	0.098
5[3]	34-37	1:4:1	80.78	17.65	0.605	0.238	82.61	15.81	0.633	0.100
			One-Third Feed Lot							
			Steer 666				Steer 669			
1	1-5	1:1:0	84.66	14.10	0.458	0.101	86.12	12.76	0.384	0.088
2	8-13	1:3:0	82.75	15.82	0.476	0.157	82.68	16.01	0.434	0.142
3	17-22	1:5:0	79.17	19.28	0.585	0.213	81.51	16.94	0.537	0.209
4	25-30	1:4:1	80.77	17.47	0.676	0.265	80.26	17.94	0.630	0.294
5[3]	34-37	1:4:1	84.13	14.44	0.533	0.217	81.47	16.81	0.585	0.281
			Two-Thirds-Feed Lot							
			Steer 652[1]				Steer 665			
1	1-5	1:1:0	86.32	12.58	0.405	0.099	85.39	13.52	0.423	0.098
2	8-13	1:3:0	82.85	15.88	0.450	0.136	81.59	17.13	0.445	0.146
3	17-22	1:5:0	81.90	16.85	0.573	0.155	80.69	17.93	0.491	0.180
4	25-30	1:4:1	83.76	14.92	0.571	0.177	79.47	18.92	0.606	0.254
5[3]	34-37	1:4:1	83.85	15.21	0.540	0.215	80.69	17.72	0.582	0.240
			Full-Feed Lot							
			Steer 663[2]				Steer 661			
1	1-5	1:1:0	85.61	13.33	0.412	0.096	86.05	12.87	0.397	0.093
2	8-13	1:3:0	82.37	16.27	0.486	0.145	82.29	16.56	0.398	0.119
3	17-22	1:5:0	80.78	17.91	0.530	0.148	79.83	18.85	0.448	0.148
4	25-30	1:4:1	81.39	16.77	0.611	0.287	81.12	17.45	0.571	0.207
5	34-37	1:4:1	.....	.....	.....	.....	83.18	15.39	0.537	0.220

[1] Removed at end of 34th week. [2] Removed at end of 30th week.
[3] Steers 650, 666, and 652 were on full feed in this period.

TABLE 8.—AVERAGE CHEMICAL COMPOSITION OF FECES
(Results expressed in percent of fresh substance)

Period	Weeks	Ratio of hay to corn to linseed meal	Water	Organic matter	Nitrogen	Phosphorus
1	1-5	1:1:0	85.41	13.43	0.431	0.098
2	8-13	1:3:0	82.80	15.89	0.476	0.142
3	17-22	1:5:0	80.87	17.74	0.550	0.172
4	25-30	1:4:1	80.94	17.41	0.630	0.240
5	34-37	1:4:1	82.39	16.15	0.574	0.216

AMOUNTS AND COMPOSITION OF URINE

The weights of the urine excreted and the percentages of total nitrogen and phosphorus in the urine are given in Tables 9 to 12, inclusive. In the case of the phosphorus determination, the results obtained were none too satisfactory; which fact, along with the pressure of other duties, caused this work to be abandoned after the thirteenth week. The results, so far as determined, are given in Table 12. While not accurate, these results serve as an indication of the amounts of phosphorus present in the urine. The excretion of phosphorus in the urine was very small except in case of Steer 656, whose urine contained much more phosphorus than the urine of the other steers. Further mention is made of this fact later in the discussion.

TABLE 9.—TOTAL URINE EXCRETED PER PERIOD
(Results expressed in pounds)

Period	Weeks	Ratio of hay to corn to linseed meal	Maintenance Lot		One-Third-Feed Lot	
			Steer 650	Steer 656	Steer 666	Steer 669
1	1-5	1:1:0	209.60	419.35	247.05	310.05
2	8-13	1:3:0	295.86	612.12	361.32	658.74
3	17-22	1:5:0	212.46	260.70	313.68	508.20
4	25-30	1:4:1	262.80	292.50	283.14	311.58
5[4]	34-37	1:4:1	207.27	172.66	258.25	201.64
Total[3]	1-37	....	1575.15	2366.48	1977.19	2782.09

			Two-Thirds-Feed Lot		Full-Feed Lot	
			Steer 652[1]	Steer 665	Steer 663[2]	Steer 661
1	1-5	1:1:0	375.80	327.45	400.70	438.70
2	8-13	1:3:0	567.24	323.82	501.84	604.86
3	17-22	1:5:0	730.68	315.60	255.72	412.62
4	25-30	1:4:1	588.66	481.44	522.30	680.10
5[4]	34-37	1:4:1	97.31	330.81	......	419.13
Total[3]	1-37	....	3337.42	2428.27	2237.62	3422.98

[1] Removed at end of 34th week. [2] Removed at end of 30th week.
[3] Includes transitional periods.
[4] Steers 650, 666, and 652 were on full feed in this period.

TABLE 10.—AVERAGE URINE EXCRETED PER WEEK
(Results expressed in pounds)

Period	Weeks	Ratio of hay to corn to linseed meal	Maintenance Lot		One-Third-Feed Lot	
			Steer 650	Steer 656	Steer 666	Steer 669
1	1-5	1:1:0	41.92	83.87	49.41	62.01
2	8-13	1:3:0	49.31	102.02	60.22	109.79
3	17-22	1:5:0	35.41	43.45	52.28	84.70
4	25-30	1:4:1	43.80	48.75	47.19	51.93
5[4]	34-37	1:4:1	51.82	43.16	64.56	50.41
Average[3]	1-37	....	42.57	63.96	53.44	75.19
			Two-Thirds-Feed Lot		Full-Feed Lot	
			Steer 652[1]	Steer 665	Steer 663[2]	Steer 661
1	1-5	1:1:0	75.16	65.49	80.14	87.74
2	8-13	1:3:0	94.54	53.97	83.64	100.81
3	17-22	1:5:0	121.78	52.60	42.62	68.77
4	25-30	1:4:1	98.11	80.24	87.05	113.35
5[4]	34-37	1:4:1	97.31	82.70	.....	104.78
Average[3]	1-37	....	98.16	65.63	74.59	92.51

[1] Removed at end of 34th week. [2] Removed at end of 30th week.
[3] Includes transitional periods.
[4] Steers 650, 666, and 652 were on full feed in this period.

TABLE 11.—TOTAL NITROGEN IN URINE PER PERIOD
(Expressed in percent of fresh urine)

Period	Weeks	Ratio of hay to corn to linseed meal	Maintenance Lot		One-Third-Feed Lot	
			Steer 650	Steer 656	Steer 666	Steer 669
1	1-5	1:1:0	0.788	0.476	0.886	0.806
2	8-13	1:3:0	0.774	0.351	0.963	0.524
3	17-22	1:5:0	0.717	0.608	1.015	0.502
4	25-30	1:4:1	1.612	1.557	2.019	2.190
5[3]	34-37	1:4:1	2.389	1.815	2.473	2.412
			Two-Thirds-Feed Lot		Full-Feed Lot	
			Steer 652[1]	Steer 665	Steer 663[2]	Steer 661
1	1-5	1:1:0	0.730	0.847	0.745	0.735
2	8-13	1:3:0	0.707	1.266	0.937	0.820
3	17-22	1:5:0	0.416	1.282	1.379	0.965
4	25-30	1:4:1	1.283	1.774	1.855	1.507
5[3]	34-37	1:4:1	1.729	1.968	.....	1.893

[1] Removed at end of 34th week. [2] Removed at end of 30th week.
[3] Steers 650, 666, and 652 were on full feed in this period.

TABLE 12.—TOTAL PHOSPHORUS IN URINE PER PERIOD
(Results expressed in percent of fresh urine)

Period	Weeks	Ratio of hay to corn to linseed meal	Maintenance Lot		One-Third-Feed Lot		Two-Thirds-Feed Lot		Full-Feed Lot	
			Steer 650	Steer 656	Steer 666	Steer 669	Steer 652	Steer 665	Steer 663	Steer 661
1	1-5	1:1:0	0.0030	0.0302	0.0034	0.0028	0.0026	0.0029	0.0025	0.0031
2	8-13	1:3:0	0.0034	0.0472	0.0036	0.0023	0.0026	0.0038	0.0030	0.0035

EXCRETION OF ORGANIC MATTER

The proportion of the organic matter of the ration which may be recovered in the manure is of especial importance to the live-stock farmer who is attempting to establish a permanent system of soil fertility. Decomposing or decomposed organic matter in the soil not only acts as a source of plant food, but it also helps to make available some of the insoluble mineral plant food, (e. g., raw rock phosphate). Also, the presence of organic matter favorably influences the physical condition of the soil.

An inspection of the data given in Tables 13 and 14 shows that, in general, the steers on the larger rations excreted a larger proportion of organic matter than the steers on the smaller rations. This was undoubtedly due to the fact that the digestibility of the dry substance and carbohydrates in Period 1, when the ration was composed of corn and clover hay in equal parts, varied inversely as the amounts of feeds consumed. Also in Period 2 there was an indication that the digestibility of the dry substance and carbohydrates varied inversely with the amounts of feeds consumed.[1] However, the differences in the percentages of organic matter excreted by the steers of the different lots during the same period were small and it seems justifiable to take an average of them. Such averages are shown in Table 27.

The percentage of organic matter excreted varied directly with the proportion of roughage in the ration, owing to the fact that the digestibility of the nutrients of the ration increased as the ratio of roughage to concentrates was varied from 1 to 1 to 1 to 5. From these results the following summary, relating to the percentage of organic matter recovered in the manure, can be made: In Period 1, an average of 33 percent of the organic matter consumed was recovered in the feces; in Period 2, 28 percent; in Period 3, 24 percent; in Period 4, 22 percent; in Period 5, 23 percent; and for the entire thirty-seven weeks of the experiment, 26 percent.

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[1] Ill. Agr. Exp. Sta. Bul. 172.

From the data given in Table 15, it is apparent that in Periods 4 and 5 the amount of feed consumed had little influence upon the percentage of organic matter excreted. The data show further that when clover hay, ground corn, and linseed meal were fed in the proportions of 1 to 4 to 1, there was excreted in the manure from 22 to 31 percent (or an average of 27 percent) as much organic matter as was consumed in the *farm-grown* feeds.

In the case of the organic matter, the plant elaborates practically its entire content from the carbon dioxid of the air and of the water and other inorganic constituents of the soil, probably not drawing upon the organic matter of the soil to any appreciable extent. However, coincident with the elaboration of organic matter by the plant from the air and water, the organic matter of the soil is being broken down by natural agencies, such as the various chemical and biological actions which are taking place in the soil. That is, the organic matter of the soil is continuously being depleted, and this depletion apparently takes place whether the soil is fallow or producing a crop.

When farm products are fed to live stock on the farm rather than sold away from the farm, about one-fourth of the organic matter built up by the plant from the carbon dioxid of the air and the water and other inorganic constituents of the soil can be returned to the soil in some organic form, and the organic matter applied in the form of manure may therefore be looked upon as clear gain over a system of farming in which all the products of the soil are sold directly from the farm. If one assumes that a considerable part of the stover, straw, etc., is also returned to the soil, as is usually the case in live-stock farming, the proportion of the organic matter of the crop which can be returned to the soil may be increased to as much as one-half or two-thirds. The results of this experiment, as well as actual good farming practice, indicate that the destruction of organic matter is not a serious proposition in live-stock farming.

It is also of interest to compare the amount of organic matter returned to the farm when the corn and clover are fed to two-year-old beef cattle, with the amount returned by a system of farming where the corn is sold and the clover is turned under as a green manure. Referring again to Table 14, it is seen in the case of the maintenance lot, that in all periods except Periods 1 and 2 more organic matter could have been returned to the soil by feeding the corn and clover than would have been returned to the soil if the corn had been sold and the clover turned under as green manure. An average of the results for the eight steers shows that in Period 1, 68.16 percent as much organic matter was recovered in the manure as was consumed in the clover hay; in Period 2, 113.96 percent; in Period 3, 146.80 percent; in Period 4, 136.38 percent; and in Period 5, 137.11 percent.

In the entire experiment there was 108.18 percent as much organic matter in the manure as would have been returned to the farm by plowing under the clover and selling off the corn.

In this connection it may be noted that in good rotations in the corn belt where two crops of corn are secured in a four- or five-year rotation (e. g., corn, corn, oats, and clover; or corn, corn, oats, clover, and wheat), corn and clover hay are produced in approximately the ratio of 1.5 to 2 parts of corn by weight, to 1 part of clover hay—a ratio not greatly different from the proportions in which these feeds were used in Periods 1 and 2. In a three-year rotation (e. g., corn, oats, and clover), corn and clover are produced in about equal amounts, or in the same proportions as these feeds were used in Period 1. Thus it is seen that in either the four- or five-year rotation noted above, as much or more organic matter could be returned to the soil by feeding the corn and clover as would be returned if the corn were sold and the clover turned under. In the three-year rotation noted above, about two-thirds as much organic matter could be returned by feeding the corn and clover as by selling the corn and plowing under the clover.

Of course the results of Periods 3, 4, and 5 are of little practical value in this connection, unless the feeder purchases corn in addition to the amount produced on the farm or feeds a part of his clover hay to other farm animals. Purchased feeds may add to the organic matter, but only at the expense of the fertility of some other farm. Consequently organic matter may be added in this manner to only a limited extent.

TABLE 13.—CONSUMPTION AND EXCRETION OF ORGANIC MATTER
(Results expressed in pounds per period)

Period	Weeks	Ratio of hay to corn to linseed meal	Total organic matter consumed	Organic matter consumed from clover hay	Total organic matter excreted in feces	Total organic matter consumed	Organic matter consumed from clover hay	Total organic matter excreted in feces
			Maintenance Lot					
			Steer 650			Steer 656		
1	1-5	1:1:0	323.03	157.43	96.64	323.01	157.43	92.74
2	8-13	1:3:0	324.18	79.10	70.26	323.71	78.94	64.96
3	17-22	1:5:0	303.32	50.06	61.43	303.32	50.06	60.57
4	25-30	1:4:1	298.23	47.76	54.60	297.13	47.76	60.36
5[1]	34-37	1:4:1	411.39	68.68	97.77	184.57	31.10	35.95
Total[3]	1-37	....	2205.67	521.18	495.98	1948.44	479.65	421.60
			One-Third-Feed Lot					
			Steer 666			Steer 669		
1	1-5	1:1:0	452.75	220.70	135.41	465.84	227.16	164.44
2	8-13	1:3:0	519.46	126.66	134.19	541.62	132.11	148.33
3	17-22	1:5:0	456.37	75.35	107.70	495.24	81.73	109.00
4	25-30	1:4:1	430.14	68.94	89.86	464.54	74.44	106.05
5[4]	34-37	1:4:1	447.24	74.48	109.28	305.33	50.86	64.99
Total[3]	1-37	....	3162.07	739.90	769.24	3110.33	749.13	806.15
			Two-Thirds-Feed Lot					
			Steer 652[1]			Steer 665		
1	1-5	1:1:0	585.09	285.19	200.69	608.57	296.55	213.65
2	8-13	1:3:0	711.03	173.48	207.27	760.92	185.53	230.77
3	17-22	1:5:0	610.19	101.57	138.60	692.42	114.43	189.91
4	25-30	1:4:1	563.02	90.11	119.01	630.89	101.11	165.11
5[4]	34-37	1:4:1	109.82	18.07	23.59	424.08	70.61	111.11
Total[3]	1-37	....	3623.24	896.82	948.92	4258.87	1014.87	1243.57
			Full-Feed Lot					
			Steer 663[2]			Steer 661		
1	1-5	1:1:0	688.39	333.83	241.66	744.71	363.01	277.51
2	8-13	1:3:0	818.39	199.24	238.27	962.34	234.17	372.06
3	17-22	1:5:0	664.65	109.40	164.14	748.97	123.28	248.92
4	25-30	1:4:1	606.73	97.01	117.49	797.15	127.78	205.77
5	34-37	1:4:1	......	......	......	546.16	88.43	123.26
Total[3]	1-37	....	3651.55	950.40	1014.45	5212.46	1243.23	1686.91

[1] Removed at end of 34th week. [2] Removed at end of 30th week.

[3] Includes transitional periods.

[4] Steers 650, 666, and 652 were on full feed in this period.

TABLE 14.—EXCRETION OF ORGANIC MATTER

(Results expressed in percent of total organic matter consumed and in percent of organic matter of hay)

Period	Weeks	Ratio of hay to corn to linseed meal	Percent of total organic matter excreted in feces	Percent of organic matter of clover hay excreted in feces	Percent of total organic matter excreted in feces	Percent of organic matter of clover hay excreted in feces
			Maintenance Lot			
			Steer 650		Steer 656	
1	1-5	1:1:0	29.92	61.39	28.71	58.91
2	8-13	1:3:0	21.67	88.82	20.38	82.29
3	17-22	1:5:0	20.25	122.71	19.97	120.99
4	25-30	1:4:1	18.31	114.32	20.31	126.38
5[4]	34-37	1:4:1	23.77	142.36	19.48	115.59
Total[3]	1-37	....	22.49	95.16	21.64	87.90
			One-Third-Feed Lot			
			Steer 666		Steer 669	
1	1-5	1:1:0	29.91	61.35	35.30	72.39
2	8-13	1:3:0	25.83	105.95	27.39	112.28
3	17-22	1:5:0	23.60	142.93	22.01	133.37
4	25-30	1:4:1	20.89	130.35	22.83	142.46
5[4]	34-37	1:4:1	24.43	146.72	21.29	127.78
Total[3]	1-37	....	24.33	103.97	25.92	107.61
			Two-Thirds-Feed Lot			
			Steer 652[1]		Steer 665	
1	1-5	1:1:0	34.30	70.37	35.11	72.05
2	8-13	1:3:0	29.75	119.48	30.33	124.38
3	17-22	1:5:0	22.71	136.46	27.43	165.96
4	25-30	1:4:1	21.14	132.07	26.17	163.30
5[4]	34-37	1:4:1	21.48	130.55	26.20	157.36
Total[3]	1-37	....	26.19	105.81	29.20	122.53
			Full-Feed Lot			
			Steer 663[2]		Steer 661	
1	1-5	1:1:0	35.11	72.39	37.27	76.45
2	8-13	1:3:0	29.11	119.59	38.66	158.88
3	17-22	1:5:0	24.70	150.04	33.24	201.91
4	25-30	1:4:1	19.36	121.11	25.81	161.03
5	34-37	1:4:1	.....	......	22.57	139.39
Total[3]	1-37	....	27.78	106.74	32.36	135.69

[1] Removed at end of 34th week. [2] Removed at end of 30th week.

[3] Includes transitional periods.

[4] Steers 650, 666, and 652 were on full feed in this period.

TABLE 15.—ORGANIC MATTER CONSUMED FROM FARM-GROWN FEEDS AND ORGANIC MATTER EXCRETED IN THE FECES

(Results expressed in pounds and in percent per period)

Period	Organic matter consumed from farm-grown feeds	Total organic matter excreted in feces	Percent excreted in feces[1]	Organic matter consumed from farm-grown feeds	Total organic matter excreted in feces	Percent excreted in feces[1]
			Maintenance Lot			
	Steer 650			Steer 656		
	lbs.	*lbs.*	*percent*	*lbs.*	*lbs.*	*percent*
4	248.57	54.60	21.97	247.47	60.36	24.39
5[2]	341.68	97.77	28.61	153.00	35.95	23.50
			One-Third-Feed Lot			
	Steer 666			Steer 669		
4	358.47	89.86	25.07	387.15	106.05	27.39
5[2]	371.65	109.28	29.40	253.71	64.99	25.62
			Two-Thirds-Feed Lot			
	Steer 652[3]			Steer 665		
4	469.34	119.01	25.36	525.78	165.11	31.40
5[2]	91.48	23.59	25.79	352.41	111.11	31.53
			Full-Feed Lot			
	Steer 663[4]			Steer 661		
4	505.88	117.49	24.22	664.31	205.77	30.97
5	......	......	.....	456.40	123.26	27.01

[1] This column expresses the total organic matter excreted in percentage of the organic matter consumed from the farm-grown feeds of the ration.

[2] Steers 650, 666, and 652 were on full feed in this period.

[3] Removed at end of 34th week. [4] Removed at end of 30th week.

EXCRETION OF NITROGEN

Inasmuch as nitrogen is one of the essential fertilizing elements in which the soil is often deficient, and as the ordinary farm ration usually contains a considerable amount of this element, largely in the form of proteins and their derivatives, it is not only of scientific interest but also of practical importance to study the amounts of nitrogen excreted by farm animals and the manner in which it is excreted.

All animals require the element nitrogen. However, an animal cannot utilize free nitrogen as it exists in the air, nor nitrogen in inorganic forms. As a matter of fact, the animal organism utilizes nitrogen only when it is in organic combination in the form of complex substances known as proteins, and to some extent in the form of the derivatives of the proteins. Thus in practice the proteins must be supplied in the food. However, before the food proteins can be utilized by the animal as a source of nitrogen, they must undergo digestion, a process by which the digestive agents change into forms which are soluble, diffusible, and available to the tissues, such portions of the feed as are capable of such changes in the digestive tract. Thus only a part of the nitrogen of the food is digested and absorbed. The other part, including various excretory substances from the body, usually amounts to from 25 to 75 percent of the total nitrogen of the food, and is excreted in the feces. The nitrogen of the feces may be used as plant food.

The animal organism requires a certain amount of nitrogen in the form of proteins (or their derivatives) for the repair and growth of the protein tissues of the body. The protein tissues are continually undergoing a breaking-down process, with the elimination of the nitrogen of the protein molecule thru the urine. This broken-down tissue must be replaced by the digested proteins from the food. Also, in the growing animal, there is an actual increase in the amount of protein tissue.

In the young animal the demands of the body for nitrogen for growth are considerable, while in the older animal they are quite small, being reduced to practically nothing in the mature animal. In the pregnant animal, a small amount of nitrogen is essential for the development of the fetus, while later, a considerable amount is essential for milk production. After all these demands of the body have been satisfied, any surplus of protein digestion products which remains may be oxidized for the energy which it contains, or it probably may be changed to fat and stored as such in the body. In either case, the nitrogen of the protein digestion products is split off and is excreted in the urine. Thus, the urine contains nitrogen from two sources: viz., (1) from the tissue protein which is broken down in the functioning of the body; and (2) from any surplus of digested protein which may remain after the demands of the body for nitrogen have been satisfied. The amount of nitrogen from the first source is practically constant, while the amount from the second source may be quite variable, depending especially upon the amount of nitrogen consumed by the animal.

Thus it is evident that the amount of nitrogen excreted, and the manner by which it is excreted by the animal may be quite variable, depending upon a number of important factors, among which may be enumerated the following: (1) The amount of protein in the ration; of course the more protein there is in the ration, the more nitrogen there will be excreted, other things being equal. (2) The digestibility of the protein; there will be more nitrogen excreted from a ration containing less digestible feeds, other things being equal. (3) The age of the animal; an older animal will require less protein for growth and, consequently, there will be a larger surplus, the nitrogen of which will be excreted. (4) The condition of the animal as regards pregnancy; a pregnant animal will utilize somewhat more of the protein of the food, leaving less nitrogen to be excreted. (5) The condition of the animal as regards milk production; a milk-producing animal will utilize more of the protein of the food, leaving less nitrogen to be excreted. Consequently, in applying the results of this or any similar experiment to other conditions, these factors should all be carefully considered.

Referring to the data given in Table 17, it may be seen that the amounts of feeds consumed apparently had but little effect upon the

TABLE 16.—CONSUMPTION AND EXCRETION OF NITROGEN
(Results expressed in pounds per period)

Period	Weeks	Ratio of hay to corn to linseed meal	Total nitrogen consumed	Nitrogen consumed in hay	Nitrogen excreted			Total nitrogen consumed	Nitrogen consumed in hay	Nitrogen excreted		
					In feces	In urine	Total			In feces	In urine	Total
			Maintenance Lot									
			Steer 650					Steer 656				
1	1-5	1:1:0	6.10	3.81	3.45	1.68	5.13	6.10	3.81	3.03	1.95	4.98
2	8-13	1:3:0	5.20	1.73	2.66	1.90	4.57	5.20	1.73	2.51	2.00	4.52
3	17-22	1:5:0	4.60	1.02	2.21	1.76	3.98	4.60	1.02	2.21	1.70	3.92
4	25-30	1:4:1	7.25	0.93	2.15	4.25	6.40	7.25	0.93	2.25	4.52	6.77
5[1]	34-37	1:4:1	10.24	1.40	3.35	4.96	8.31	4.63	0.63	1.44	3.11	4.56
Total[3]	1-37	....	44.10	11.04	18.05	19.51	37.56	37.72	10.16	15.35	18.13	33.48
			One-Third-Feed Lot									
			Steer 666					Steer 669				
1	1-5	1:1:0	8.55	5.35	4.42	2.16	6.58	8.80	5.50	4.91	2.46	7.37
2	8-13	1:3:0	8.33	2.78	4.03	3.28	7.31	8.69	2.90	4.03	3.32	7.34
3	17-22	1:5:0	6.92	1.53	3.27	2 87	6.14	7.51	1.66	3.39	3.31	6.70
4	25-30	1:4:1	10.41	1.34	3.48	5.29	8.77	11.30	1.44	3.66	6.80	10.46
5[1]	34-37	1:4:1	11.10	1.52	4.03	6.38	10.41	7.58	1.03	2.26	4.86	7.12
Total[3]	1-37	....	60.99	15.68	25.65	27.24	52.89	60.03	15.87	24.63	28.69	53.33
			Two-Thirds-Feed Lot									
			Steer 652[1]					Steer 665				
1	1-5	1:1:0	11.05	6.91	6.45	2.66	9.10	11.49	7.18	6.68	2.76	9.44
2	8-13	1:3:0	11.42	3.80	5.87	3.85	9.72	12.20	4.07	6.00	4.06	10.06
3	17-22	1:5:0	9.32	2.06	4.72	3.41	8.13	10.49	2.33	5.21	3.99	9.20
4	25-30	1:4:1	13.67	1.75	4.54	7.55	12.09	15.34	1.96	5.29	8.52	13.82
5[4]	34-37	1:4:1	2.73	0.37	0.84	1.68	2.52	10.53	1.44	3.65	6.50	10.15
Total[3]	1-37	....	68.40	19.00	30.93	28.44	59 37	82.10	21.50	56.71	35.57	72.28
			Full-Feed Lot									
			Steer 663[2]					Steer 661				
1	1-5	1:1:0	12.96	8.09	7.46	2.91	10.37	14.15	8.79	8.62	3.22	11.84
2	8-13	1:3:0	13.16	4.37	7.09	4.61	11.69	15.43	5.13	8.89	4.78	13.67
3	17-22	1:5:0	10.07	2.22	4.84	3.42	8.26	11.29	2.51	5.89	3.89	9.78
4	25-30	1:4:1	14.61	1.88	4.28	9.70	13.98	19.39	2.48	6.72	10.18	16.89
5	34-37	1:4:1	.....	....	....	....	....	13.31	1.80	4.31	7.93	12.24
Total[3]	1-37	....	65.73	20.14	30.97	26.44	57.41	101.07	26.34	47.01	41.49	88.50

[1] Removed at end of 34th week. [2] Removed at end of 30th week.
[3] Includes transitional periods.
[4] Steers 650, 666, and 652 were on full feed in this period.

percentage of nitrogen excreted. In fact, the nitrogen excretions of all eight steers, with only a few exceptions, showed little variation during a given period. Also, there were only slight variations when the entire thirty-seven weeks of the experiment are considered. Consequently, it seems justifiable to take an average of the results of the eight steers as representing the percentage of nitrogen excreted during each period. From these results (Table 27) it is apparent that

TABLE 17.—EXCRETION OF NITROGEN

(Results expressed in percent of total nitrogen consumed, and in percent of nitrogen of hay)

Period	Weeks	Ratio of hay to corn to linseed meal	In percent of total nitrogen	In percent of nitrogen of clover hay	In percent of total nitrogen	In percent of nitrogen of clover hay
			Maintenance Lot			
			Steer 650		Steer 656	
1	1–5	1:1:0	84.10	134.65	81.56	130.71
2	8–13	1:3:0	87.77	264.16	87.07	261.27
3	17–22	1:5:0	86.68	390.20	85.25	384.31
4	25–30	1:4:1	88.22	688.17	93.35	727.96
5[4]	34–37	1:4:1	81.21	593.57	98.32	723.81
Total[3]	1–37	....	85.18	340.22	88.77	329.53
			One-Third-Feed Lot			
			Steer 666		Steer 669	
1	1–5	1:1:0	76.95	122.99	83.74	134.00
2	8–13	1:3:0	87.69	262.95	84.60	253.10
3	17–22	1:5:0	88.73	401.31	89.45	403.61
4	25–30	1:4:1	84.28	654.48	92.58	726.39
5[4]	34–37	1:4:1	93.81	684.87	93.93	691.26
Total[3]	1–37	....	86.72	337.31	88.84	336.04
			Two-Thirds-Feed Lot			
			Steer 652[1]		Steer 665	
1	1–5	1:1:0	82.39	131.69	82.11	131.48
2	8–13	1:3:0	85.13	255.79	82.50	247.17
3	17–22	1:5:0	87.19	394.66	87.71	394.85
4	25–30	1:4:1	88.45	690.86	90.06	705.10
5[4]	34–37	1:4:1	92.31	681.08	96.41	704.86
Total[3]	1–37	....	86.80	312.47	88.03	336.19
			Full-Feed Lot			
			Steer 663[2]		Steer 661	
1	1–5	1:1:0	80.02	128.18	83.67	134.70
2	8–13	1:3:0	88.83	267.51	88.61	266.47
3	17–22	1:5:0	82.06	372.07	86.66	389.64
4	25–30	1:4:1	95.68	743.62	87.14	681.05
5	34–37	1:4:1	......	......	91.94	680.00
Total[3]	1–37	....	87.34	285.05	87.56	332.19

[1] Removed at end of 34th week. [2] Removed at end of 30th week.

[3] Includes transitional periods.

[4] Steers 650, 666, and 652 were on full feed in this period.

the total excretory nitrogen (urine and feces) made up 82 percent of the total nitrogen consumed in Period 1; 87 percent, in Period 2; 87 percent, in Period 3; 90 percent, in Period 4; 93 percent, in Period 5; and 87 percent for the entire experiment of thirty-seven weeks.

In an experiment with six mature milch cows at this station,[1] 80.32 percent of the nitrogen consumed was excreted in the feces and urine, and 20.12 percent was excreted in the milk. In an experiment with two milch cows at the Pennsylvania Station,[2] 84.64 percent of the nitrogen appeared in the feces and urine and 16.76 percent in the milk. Warington[3] calculates from experiments by Lawes and Gilbert at the Rothamsted Station that in the case of a mature fat steer 96 percent of the nitrogen of the ration was excreted. A milch cow excreted 75 percent of the nitrogen in the manure, while a calf excreted only 31 percent. Thus the results of our own experiment do not differ materially from the results of other investigations with cattle, except in the case of the milch cow of Lawes and Gilbert. It is of interest to note that the addition of nitrogen in the form of linseed meal to the ration in Periods 4 and 5 caused not only an increase in the absolute amounts of nitrogen excreted but also an increase in the percentage of nitrogen excreted.

Inasmuch as the nitrogen is excreted in both the feces and the urine, it is of interest and practical value to note what proportion of the total amount excreted is in each. Apparently the amount of feed consumed had little or no influence upon the way the nitrogen was excreted, i. e., whether it was in the feces or in the urine (Table 18). The averages of these results (Table 19) show the distribution of the nitrogen excreted to have been in Period 1, 68.5 percent in the feces and 31.5 percent in the urine; in Period 2, 59 percent in the feces and 41 percent in the urine; in Period 3, 56 percent in the feces and 44 percent in the urine; in Period 4, 36 percent in the feces and 64 percent in the urine; in Period 5, 35 percent in the feces and 65 percent in the urine; and in the entire experiment of thirty-seven weeks, 50 percent in the feces and 50 percent in the urine.

In the Illinois experiment with milch cows already noted, 44 percent of the nitrogen excreted in the manures was in the feces and 56 percent in the urine. In the Pennsylvania experiment with milch cows, 37 percent of the nitrogen was in the feces and 63 percent in the urine. According to Van Slyke,[4] 49 percent of the nitrogen is excreted in the feces and 51 percent in the urine, in the case of cattle.

From these figures it is evident that a large percentage of the nitrogen excreted is in the urine. Thus it is important to conserve the urine of our farm animals by using plenty of bedding, water-tight stalls and barnyards, and by other suitable means. If the urine in this experiment had been wasted, from one-third to two-thirds of the nitrogen of the manure would have been lost. Incidentally, according to Van Slyke, 85 percent of the potassium (potash) excreted is in the urine and 15 percent in the feces, in the case of cattle. Inasmuch as the fertilizing ingredients of the liquid excrement are on the whole more available for plant growth than those of the solid excrement, and inasmuch as nitrogen and potassium are expensive fertilizing elements and occur in manure in large amounts, it is evident that at least half the fertilizing value of cattle manure is in the urine.

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[1] Hopkins: Soil Fertility and Permanent Agriculture, p. 201.

[2] Penn. Agr. Exp. Sta. Ann. Rpt. 1899-1900, p. 321.

[3] Chemistry of the Farm, p. 214.

[4] Fertilizers and Crops, p. 295.

TABLE 18.—EXCRETION OF NITROGEN
(Results expressed in percent of total nitrogen excreted)

Period	Weeks	Ratio of hay to corn to linseed meal	In feces	In urine	In feces	In urine	In feces	In urine
			Maintenance Lot					
			Steer 650		Steer 656		Average	
1	1-5	1:1:0	67.25	32.75	60.84	39.16	64.05	35.95
2	8-13	1:3:0	58.21	41.79	55.53	44.47	56.87	43.13
3	17-22	1:5:0	55.53	44.47	56.38	43.62	55.95	44.05
4	25-30	1:4:1	33.59	66.41	33.23	66.77	33.41	66.59
5	34-37	1:4:1	40.31	59.69	31.58	68.42	35.94	64.06
Average[3]	1-37	....	48.06	51.94	45.85	54.15	46.95	53.05
			One-Third-Feed Lot					
			Steer 666		Steer 669		Average	
1	1-5	1:1:0	67.17	32.82	66.62	33.38	66.89	33.11
2	8-13	1:3:0	55.13	44.87	54.90	45.10	55.01	44.99
3	17-22	1:5:0	53.26	46.74	50.60	49.40	51.93	48.07
4	25-30	1:4:1	39.68	60.32	34.99	65.01	37.33	62.67
5	34-37	1:4:1	38.71	61.29	31.74	68.26	35.22	64.78
Average[3]	1-37	....	48.50	51.50	46.18	53.82	47.34	52.66
			Two-Thirds-Feed Lot					
			Steer 652[1]		Steer 665		Average	
1	1-5	1:1:0	70.88	29.12	70.76	29.24	70.82	29.18
2	8-13	1:3:0	60.39	39.61	59.64	40.36	60.01	39.99
3	17-22	1:5:0	58.06	41.94	56.63	43.37	57.34	42.66
4	25-30	1:4:1	37.55	62.45	38.28	61.72	37.91	62.09
5	34-37	1:4:1	33.33	66.67	35.96	64.04	34.64	65.36
Average[3]	1-37	....	52.10	47.90	50.79	49.21	51.44	48.56
			Full-Feed Lot					
			Steer 663[2]		Steer 661		Average	
1	1-5	1:1:0	71.94	28.06	72.80	27.20	72.37	27.63
2	8-13	1:3:0	60.65	39.35	65.03	34.97	62.84	37.16
3	17-22	1:5:0	58.60	41.40	60.22	39.78	59.41	40.59
4	25-30	1:4:1	30.62	69.38	39.79	60.21	35.20	64.80
5	34-37	1:4:1	.....	.....	35.21	64.79	35.21	64.79
Average[3]	1-37	....	53.95	46.05	53.12	46.88	53.53	46.47

[1] Removed at end of 34th week. [2] Removed at end of 30th week.
[3] Includes transitional periods.

TABLE 19.—AVERAGE EXCRETION OF NITROGEN BY ALL STEERS
(Results expressed in percent of total nitrogen excreted)

Period	Weeks	Ratio of hay to corn to linseed meal	In feces	In urine
1	1–5	1:1:0	68.53	31.47
2	8–13	1:3:0	58.68	41.32
3	17–22	1:5:0	56.16	43.84
4	25–30	1:4:1	35.96	64.04
5	34–37	1:4:1	35.25	64.75
Average.......	1–37	....	49.82	50.18

The data given in Table 20 show that in Periods 4 and 5 the amount of the ration consumed had no apparent influence upon the percentage of nitrogen excreted. Also the data show that 123 to 177, or an average of 160, percent as much nitrogen was excreted in the manure as was consumed in the farm-grown feeds. In other words, when the ration consisted of clover hay, ground corn, and linseed meal in the proportions of 1 to 4 to 1, 1.6 pounds of nitrogen were excreted in the manure for every pound of nitrogen removed from the soil (or air) by the hay and corn of the ration. Altho some of

TABLE 20.—NITROGEN CONSUMED FROM FARM-GROWN FEEDS AND TOTAL NITROGEN EXCRETED
(Results expressed in pounds and in percent per period)

Period	Nitrogen consumed from farm-grown feeds	Total nitrogen excreted	Percent excreted[1]	Nitrogen consumed from farm-grown feeds	Total nitrogen excreted	Percent excreted[1]
	Maintenance Lot					
	Steer 650			Steer 656		
	lbs.	*lbs.*	*percent*	*lbs.*	*lbs.*	*percent*
4	4.01	6.40	159.60	4.01	6.77	168.83
5[2]	5.69	8.31	146.05	2.57	4.56	177.43
	One-Third-Feed Lot					
	Steer 666			Steer 669		
4	5.74	4.67	122.91	6 25	10.46	167.36
5[2]	6.17	4.93	125.15	4.19	7.12	169.93
	Two-Thirds-Feed Lot					
	Steer 652[3]			Steer 665		
4	7.56	12.09	159.92	8.49	13.82	162.78
5[2]	1.53	2.52	164.70	5.86	10.15	173.21
	Full-Feed Lot					
	Steer 663[4]			Steer 661		
4	8.03	13.98	174.10	10.73	16.89	157.41
5	....	.....	......	7.46	12.24	164.08

[1] This column expresses the total nitrogen excreted in percentage of the nitrogen consumed from the farm-grown feeds of the ration.
[2] Steers 650, 666, and 652 were on full feed in this period.
[3] Removed at end of 34th week.
[4] Removed at end of 30th week.

the nitrogen of the manure undoubtedly would be lost even under optimum conditions (probably 10 to 15 percent), still, if reasonable care were exercised in the conservation of the manure, the quantity of nitrogen returned to the soil in the manure would be equal to and probably exceed the nitrogen removed by the clover hay and the corn, especially is this seen to be true when one considers the amount of nitrogen added to the soil by the roots and stubble of the clover plants. In this connection it should be noted that in case nitrogenous by-products were for any reason unavailable, it obviously would be impossible to maintain the fertility by this method alone.

It is also of interest to compare the amount of nitrogen which was returned in the form of manure, with the amount which would have been returned by a system of farming in which the corn is sold and the clover is plowed under. Referring again to Table 17, it is seen that in all the periods of this experiment more nitrogen was returned in the manure than was contained in the clover hay fed. An average of the results for the eight steers shows that in Period 1, 131.05 percent as much nitrogen was returned in the manure as would have been returned by plowing under the clover; in Period 2, 259.80 percent; in Period 3, 391.33 percent; in Period 4, 702.20 percent; in Period 5, 679.92 percent; and for the entire experiment, 326.12 percent. The large increase in Periods 4 and 5 is due to the addition of the nitrogenous concentrate (linseed meal) to the ration.

It has already been noted on page 140 that in rotations where two crops of corn are secured in four or five years, corn and clover hay are produced in a proportion not greatly different from that in which these feeds were used in Periods 1 and 2. In a three-year rotation the proportions of corn and clover are approximately the same as fed in Period 1. Thus it is apparent that when corn and clover hay are fed in approximately the same proportions in which they should be produced in a good corn-belt rotation, considerably more nitrogen can be returned to the soil than under the other system of farming assumed immediately above. As previously explained (page 140) the results in Periods 3, 4, and 5 are of practical value only in case the feeder feeds a part of his clover to other stock or purchases corn additional to that produced on the farm.

EXCRETION OF PHOSPHORUS

Inasmuch as phosphorus is the key to permanent systems of agriculture, in a large part of the corn belt at least, the excretion of phosphorus should be of considerable interest to the practical farmer as well as to the scientific investigator.

As already stated, practically all of the phosphorus excreted by the animals used in this study was in the feces, only small amounts being found in the urine, except in the case of Steer 656, whose urine contained twenty times as much phosphorus as the urine of some of the other steers. In the Illinois and Pennsylvania experiments with milch cows previously quoted, only very small amounts of phosphorus were excreted in the urine. According to Van Slyke,[1] the cow and horse excrete practically all the phosphorus in the feces. In the case of the hog, 12 percent of the excreted phosphorus is in the urine, while in the case of the sheep 5 percent is in the urine. Why Steer 656 was an exception to the general rule, we are unable to explain.

It is seen from the data given in Table 22 that the amount of feed consumed apparently had no effect upon the percentage of the phosphorus of the total ration that was excreted. However, it will be noted that there is considerably more variation between the steers in the same period than in the case of the nitrogen excreted. The percentage of phosphorus excreted by Steer 656 is considerably lower than that excreted by the other steers, owing to the fact already noted, that this steer excreted considerable phosphorus in his urine. If the phosphorus excreted in the feces in Periods 1 and 2 is added to the amounts of phosphorus excreted in the urine in these periods (see Tables 9 and 12), and then the percentage of total phosphorus excreted calculated, it is found that in Period 1, 87.79 percent, and in Period 2, 84.94 percent of the total phosphorus consumed was excreted. These results are not essentially different from the results from the other steers during these periods. It is possible that the variations among the other steers would be lessened if accurate determinations of the amounts of phosphorus in the urine were available and included in the amounts of phosphorus excreted.

Table 27 shows the average percentage of phosphorus excreted by all the steers excepting Steer 656, which has been omitted for obvious reasons. From these data it is seen that of the total amount of phosphorus excreted, practically all was in the feces, and that the quantity of feed consumed had no influence upon the percentage of phosphorus excreted. In Period 1, 93 percent of the total phosphorus consumed was excreted; in Period 2, 96 percent; in Period 3, 85 percent; in Period 4, 81 percent; in Period 5, 81 percent; and in the entire experiment, 87 percent.

In the experiment at this station with four milch cows, already mentioned, about 73 percent of the phosphorus of the ration was excreted in the manures and about 22 percent in the milk. In the Pennsylvania experiment with two milch cows, about 71 percent of the phosphorus of the ration was excreted in the manures and about 21 percent in the milk. One would naturally expect that milch cows would excrete in the manures a smaller proportion of the phosphorus of their rations than two-year-old steers.

Table 23 shows the amounts of phosphorus consumed from the farm-grown feeds (i.e., the corn and clover hay); the amounts of phosphorus excreted from the total ration (i.e., the clover hay, corn, and linseed meal); and the phosphorus excreted from the total ration expressed in the percentage of the phosphorus consumed from the farm-grown feeds of the ration.

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[1] Fertilizers and Crops, p. 295.

The results pertaining to Steer 656 need not be considered, owing to the fact, already explained, that he excreted a large but undetermined part of the phosphorus in the urine, while the other steers excreted the phosphorus largely thru the feces. As in the case of the organic matter and the nitrogen, so with the phosphorus, the

TABLE 21.—CONSUMPTION AND EXCRETION OF PHOSPHORUS
(Results expressed in pounds per period)

Period	Weeks	Ratio of hay to corn to linseed meal	Total phosphorus consumed	Phosphorus consumed in hay	Phosphorus excreted in feces	Total phosphorus consumed	Phosphorus consumed in hay	Phosphorus excreted in feces
			Maintenance Lot					
			Steer 650			Steer 656		
1	1-5	1:1:0	0.868	0.358	0.794	0.868	0.358	0.632
2	8-13	1:3:0	0.871	0.156	0.860	0.870	0.156	0.477
3	17-22	1:5:0	0.890	0.081	0.799	0.890	0.081	0.325
4	25-30	1:4:1	1.188	0.077	0.966	1.188	0.077	0.357
5[4]	34-37	1:4:1	1.678	0.127	1.319	0.759	0.057	0.229
Total[3]	1-37	....	7.309	0.960	6.245	6.265	0.883	2.686
			One-Third-Feed Lot					
			Steer 666			Steer 669		
1	1-5	1:1:0	1.216	0.502	0.988	1.251	0.517	1.119
2	8-13	1:3:0	1.396	0.250	1.331	1.456	0.261	1.321
3	17-22	1:5:0	1.341	0.122	1.191	1.456	0.132	1.340
4	25-30	1:4:1	1.725	0.111	1.367	1.852	0.120	1.707
5[1]	34-37	1:4:1	1.820	0.137	1.638	1.243	0.094	1.088
Total[3]	1-37	....	10.149	1.363	8.921	10.009	1.380	9.065
			Two-Thirds-Feed Lot					
			Steer 652[1]			Steer 665		
1	1-5	1:1:0	1.583	0.649	1.581	1.635	0.675	1.528
2	8-13	1:3:0	1.913	0.342	1.774	2.016	0.366	1.965
3	17-22	1:5:0	1.808	0.165	1.277	2.036	0.185	1.916
4	25-30	1:4:1	2.240	0.145	1.409	2.514	0.163	2.216
5[4]	34-37	1:4:1	0.417	0.033	0.255	1.726	0.130	1.504
Total[3]	1-37	....	11.385	1.652	8.843	13.718	1.869	12.507
			Full-Feed Lot					
			Steer 663[2]			Steer 661		
1	1-5	1:1:0	1.856	0.760	1.732	1.994	0.826	2.005
2	8-13	1:3:0	2.209	0.393	2.072	2.584	0.462	2.668
3	17-22	1:5:0	1.954	0.177	1.366	2.190	0.200	1.951
4	25-30	1:4:1	2.392	0.156	2.011	3.178	0.206	2.427
5	34-37	1:4:1	.....	.....	.....	2.182	0.163	1.758
Total[3]	1-37	....	11.024	1.750	9.457	16.794	2.290	14.616

[1] Removed at end of 34th week. [2] Removed at end of 30th week.

[3] Includes transitional periods.

[4] Steers 650, 666, and 652 were on full feed in this period.

percentages excreted in Periods 4 and 5 apparently were not influenced by the amounts of feed consumed. It is also seen that during these periods, when the ration consisted of clover hay, ground corn, and linseed meal in the proportions of 1 to 4 to 1, there was excreted in the manure 110 to 160 percent as much phosphorus as was consumed in the farm-grown feeds. In other words, an average of 1.4 pounds of phosphorus was excreted in the manure (principally in the feces)

TABLE 22.—EXCRETION OF PHOSPHORUS

(Results expressed in percent of total phosphorus consumed, and in percent of phosphorus of hay)

Period	Weeks	Ratio of hay to corn to linseed meal	In percent of total phosphorus	In percent of phosphorus of clover hay	In percent of total phosphorus	In percent of phosphorus of clover hay
			Maintenance Lot			
			Steer 650		Steer 656	
1	1-5	1:1:0	91.48	221.79	72.81	176.54
2	8-13	1:3:0	98.76	551.28	54.82	305.77
3	17-22	1:5:0	89.79	986.42	36.54	401.23
4	25-30	1:4:1	81.29	1254.55	30.02	463.64
5[4]	34-37	1:4:1	78.60	1038.58	30.13	401.75
Total[3]	1-37	....	85.45	650.52	42.87	304.19
			One-Third-Feed Lot			
			Steer 666		Steer 669	
1	1-5	1:1:0	81.25	196.81	89.42	216.44
2	8-13	1:3:0	95.34	532.40	90.79	506.13
3	17-22	1:5:0	88.87	976.23	92.09	1015.15
4	25-30	1:4:1	79.28	1231.53	92.21	1422.50
5[4]	34-37	1:4:1	89.98	1195.62	87.50	1157.45
Total[3]	1-37	....	87.89	654.51	90.57	656.88
			Two-Thirds-Feed Lot			
			Steer 652[1]		Steer 665	
1	1-5	1:1:0	99.89	243.61	93.44	226.37
2	8-13	1:3:0	92.72	518.71	96.00	536.89
3	17-22	1:5:0	70.61	773.94	94.10	1035.68
4	25-30	1:4:1	62.89	971.72	88.12	1359.51
5	34-37	1:4:1	61.15	772.73	87.12	1156.92
Total[3]	1-37	....	77.67	535.29	91.17	669.18
			Full-Feed Lot			
			Steer 663[2]		Steer 661	
1	1-5	1:1:0	93.34	227.89	100.55	242.73
2	8-13	1:3:0	93.80	527.23	103.24	577.49
3	17-22	1:5:0	69.91	771.75	89.07	975.50
4	25-30	1:4:1	84.09	1289.10	76.36	1178.16
5	34-37	1:4:1	.....	......	80.57	1078.53
Total[3]	1-37	....	85.79	540.40	87.03	638.25

[1] Removed at end of 34th week. [2] Removed at end of 30th week.

[3] Includes transitional periods.

[4] Steers 650, 666, and 652 were on full feed in this period.

for every pound of phosphorus removed from the soil by the hay and corn that were fed. It is true with phosphorus, as with nitrogen, that some of it may be lost before the manure is put on the soil; but if the manure is properly cared for, most of the element can be returned. Under conditions such as prevailed during Periods 4 and 5 of this experiment, the phosphorus content of the soil would not only be maintained but it probably would be increased.

It is also of interest to compare the amount of phosphorus returned to the farm when the corn and clover are fed to two-year-old beef cattle, with the amount returned when the corn is sold and the clover is plowed under for manure. From Table 22 it is seen that considerably more phosphorus was excreted in the manure than would have been returned to the farm had the clover been plowed under. An average of the results for the eight steers shows that in Period 1, 225.09 percent as much phosphorus was returned in the manure as was in the clover hay consumed; in Period 2, 550.02 percent; in Period 3, 933.52 percent; in Period 4, 1,243.87 percent; in Period 5, 1,066.64 percent; and in the entire experiment, 620.72 percent. It seems safe to conclude, therefore, that much more phosphorus can

TABLE 23.—PHOSPHORUS CONSUMED FROM FARM-GROWN FEEDS AND TOTAL PHOSPHORUS EXCRETED

(Results expressed in pounds and in percent per period)

Period	Phosphorus consumed in farm feeds	Total phosphorus excreted	Percent excreted[1]	Phosphorus consumed in farm feeds	Total phosphorus excreted	Percent excreted[1]
			Maintenance Lot			
	Steer 650			Steer 656		
	lbs.	*lbs.*	*percent*	*lbs.*	*lbs.*	*percent*
4	0.682	0.966	141.64	0.682	0.357	......
5[2]	0.968	1.319	136.26	0.437	0.229	......
			One-Third-Feed Lot			
	Steer 666			Steer 669		
4	0.995	1.367	137.39	1.064	1.707	160.43
5[2]	1.050	1.638	156.00	0.717	1.088	151.74
			Two-Thirds-Feed Lot			
	Steer 652[3]			Steer 665		
4	1.286	1.409	109.56	1.443	2.216	153.57
5[2]	0.230	0.255	110.87	0.996	1.504	151.00
			Full-Feed Lot			
	Steer 663[4]			Steer 661		
4	1.365	2.011	147.33	1.825	2.427	132.99
5	.....	.....	......	1.268	1.758	138.64

[1] This column expresses the total phosphorus excreted in percentage of the phosphorus consumed from the farm-grown feeds of the ration.

[2] Steers 650, 666, and 652 were on full feed in this period.

[3] Removed at end of 34th week.

[4] Removed at end of 30th week.

be returned to the farm by feeding the crops to two-year-old beef cattle than can be returned in a system of farming in which the corn is sold and the clover plowed under.

Even in Periods 1 and 2, when corn and clover hay were fed in approximately the same proportions as they are grown in a good rotation, it would have been possible to return to the soil relatively much more phosphorus than could have been returned by the other system of farming assumed above.

FINANCIAL STATEMENT

It is of interest to calculate the value of the fertilizing elements of the manure on the basis of their cost in commercial fertilizers. Accordingly, we have assumed the following prices: for nitrogen 15 cents; for phosphorus 10 cents; and for potassium 6 cents per pound; which values are approximately the average market prices of these fertilizing elements under ordinary conditions. Unfortunately, the consumption and excretion of potassium was not determined. However, assuming the average potassium content of clover hay, corn, and linseed meal, and assuming further that 90 percent of the potassium consumed was excreted, it is possible to calculate the approximate amounts of potassium in the manure.

TABLE 24.—COMMERCIAL VALUE OF THE NITROGEN, PHOSPHORUS, AND POTASSIUM EXCRETED PER PERIOD[1]

Period	Weeks	Ratio of hay to corn to linseed meal	Maintenance Lot		One-Third-Feed Lot	
			Steer 650	Steer 656	Steer 666	Steer 669
1	1-5	1:1:0	$1.06	$1.02	$1.38	$1.52
2	8-13	1:3:0	0.92	0.87	1.45	1.46
3	17-22	1:5:0	0.78	0.72	1.20	1.31
4	25-30	1:4:1	1.19	1.19	1.64	1.94
5[2]	34-37	1:4:1	1.56	0.78	1.92	1.31
Total	1-37	....	$7.24	$6.17	$10.21	$10.29
			Two-Thirds-Feed Lot		Full-Feed Lot	
			Steer 652[3]	Steer 665	Steer 663[4]	Steer 661
1	1-5	1:1:0	$1.90	$1.96	$2.17	$2.37
2	8-13	1:3:0	1.94	2.03	2.30	2.72
3	17-22	1:5:0	1.56	1.81	1.61	1.93
4	25-30	1:4:1	2.19	2.56	2.57	3.11
5[2]	34-37	1:4:1	0.46	1.85	....	2.25
Total	1-37	....	$11.41	$14.98	$11.20	$15.97

[1] This table is based upon the assumption that nitrogen costs 15 cents, phosphorus 10 cents, and potassium 6 cents per pound if purchased in commercial fertilizers.

[2] Steers 650, 666, and 652 were on full feed in this period.

[3] Removed at end of 34th week. [4] Removed at end of 30th week.

The total commercial value of the fertilizing elements as shown in Table 24, has been calculated by using the amounts of nitrogen actually excreted (see Table 16), the amounts of phosphorus actually excreted (see Table 21), and the calculated amounts of potassium excreted, together with the respective prices of the elements stated above.

An inspection of these data shows that the fertilizing elements in the manure of Steers 650 and 656 of the maintenance lot, for the entire thirty-seven weeks, would have cost $7.24 and $6.17, respectively, if they had been purchased in the form of commercial fertilizers; of Steers 666 and 669 of the one-third-feed lot, $10.21 and $10.29, respectively; of Steers 652 and 665 of the two-thirds-feed lot, $11.41 and $14.98, respectively; and of Steers 663 and 661 of the full-feed lot, $11.20 and $15.97, respectively. The individual farmer must not assume that these fertilizing elements will necessarily have these values, as these will depend largely upon the requirements of his soil and his system of crop production. However, these figures do show conclusively that the fertilizing value of the manure from fattening steers is no small item and should be considered in the balance sheet showing the profit or loss of feeding operations.

Table 25 shows the same values as those in Table 24, calculated per week. From this table it is seen that the value of the manure varied directly with the amount of the ration consumed; that the

TABLE 25.—COMMERCIAL VALUE OF THE NITROGEN, PHOSPHORUS, AND POTASSIUM EXCRETED PER WEEK[1]

Period	Weeks	Ratio of hay to corn to linseed meal	Maintenance Lot			One-Third-Feed Lot		
			Steer 650	Steer 656	Average	Steer 666	Steer 669	Average
1	1–5	1:1:0	$0.21	$0.20	$0.20	$0.28	$0.30	$0.29
2	8–13	1:3:0	0.15	0.15	0.15	0.24	0.24	0.24
3	17–22	1:5:0	0.13	0.12	0.12	0.20	0.22	0.21
4	25–30	1:4:1	0.20	0.20	0.20	0.27	0.32	0.30
5[2]	34–37	1:4:1	0.39	0.19	0.29	0.48	0.33	0.40
Average	1–37	....	$0.20	$0.17	$0.18	$0.28	$0.28	$0.28
			Two-Thirds-Feed Lot			Full-Feed Lot		
			Steer 652	Steer 665	Average	Steer 663	Steer 661	Average
1	1–5	1:1:0	$0.38	$0.39	$0.38	$0.43	$0.47	$0.45
2	8–13	1:3:0	0.32	0.34	0.33	0.38	0.45	0.41
3	17–22	1:5:0	0.26	0.30	0.28	0.27	0.32	0.29
4	25–30	1:4:1	0.36	0.43	0.40	0.43	0.52	0.47
5[2]	34–37	1:4:1	0.46	0.46	0.46	....	0.56	0.56
Average	1–37	....	$0.34	$0.40	$0.37	$0.37	$0.43	$0.40

[1] This table is based upon the assumption that nitrogen costs 15 cents, phosphorus, 10 cents, and potassium, 6 cents per pound if purchased in commercial fertilizers.

[2] Steers 650, 666, and 652 were on full feed in this period.

presence of a considerable amount of clover hay in the ration increased the value of the manure, while the presence of a large proportion of corn decreased the value of the manure; and that the addition of linseed meal to the ration increased the value of the manure. In Period 1, when the ration consisted of clover hay and ground corn in equal parts, the fertilizing elements in the manure of the maintenance steers would have cost 20 cents; of the one-third-feed steers, 29 cents;

TABLE 26.—COST OF FEEDS CONSUMED COMPARED WITH COMMERCIAL VALUE OF MANURE EXCRETED[1]

Period	Weeks	Ratio of hay to corn to linseed meal	Value of feed	Value of manure	Value of manure in percent of value of feed	Value of feed	Value of manure	Value of manure in percent of value of feed
			Maintenance Lot					
			Steer 650			Steer 656		
1	1-5	1:1:0	$2.89	$1.06	36.68	$2.89	$1.02	35.29
2	8-13	1:3:0	3.35	0.92	27.46	3.35	0.87	25.97
3	17-22	1:5:0	3.23	0.78	24.15	3.23	0.72	22.29
4	25-30	1:4:1	3.78	1.19	31.48	3.79	1.19	31.40
5	34-37	1:4:1	5.31	1.56	29.38	2.40	0.78	32.50
Total	1-37	....	$24.75	$7.24	29.25	$21.45	$6.17	28.76
			One-Third-Feed Lot					
			Steer 666			Steer 669		
1	1-5	1:1:0	$4.05	$1.38	34.07	$4.17	$1.52	36.45
2	8-13	1:3:0	5.37	1.45	27.00	5.60	1.46	26.07
3	17-22	1:5:0	4.87	1.20	24.64	5.28	1.31	24.81
4	25-30	1:4:1	5.46	1.64	30.04	5.90	1.94	32.88
5	34-37	1:4:1	5.76	1.92	33.33	3.93	1.31	33.33
Total	1-37	....	$34.55	$10.21	29.55	$34.29	$10.29	30.01
			Two-Thirds-Feed Lot					
			Steer 652			Steer 665		
1	1-5	1:1:0	$5.23	$1.90	36.33	$5.44	$1.96	36.03
2	8-13	1:3:0	7.35	1.94	26.39	7.87	2.03	25.79
3	17-22	1:5:0	6.56	1.56	23.78	7.39	1.81	24.49
4	25-30	1:4:1	7.14	2.19	30.67	8.01	2.56	31.96
5	34-37	1:4:1	1.40	0.46	32.86	5.46	1.85	33.88
Total	1-37	....	$39.43	$11.41	28.94	$47.03	$14.98	31.85
			Full-Feed Lot					
			Steer 663			Steer 661		
1	1-5	1:1:0	$6.13	$2.17	35.40	$6.66	$2.37	35.58
2	8-13	1:3:0	8.45	2.30	27.22	9.93	2.72	27.39
3	17-22	1:5:0	7.07	1.61	22.77	7.97	1.93	24.22
4	25-30	1:4:1	7.68	2.57	33.46	10.12	3.11	30.73
5	34-37	1:4:1	....	....	....	6.84	2.25	32.89
Total	1-37	....	$38.65	$11.20	28.98	$57.45	$15.97	27.79

[1] Corn valued at 56 cents per bushel, hay at $10 per ton, linseed meal at $40 per ton, nitrogen at 15 cents per pound, phosphorus at 10 cents per pound, and potassium at 6 cents per pound.

of the two-thirds-feed steers, 38 cents; and of the full-feed steers, 45 cents per head per week. In Period 2, when the ration consisted of one part of clover hay and three parts of ground corn, the fertilizing elements in the manure of the maintenance steers would have cost 15 cents; of the one-third-feed steers, 24 cents; of the two-thirds-feed steers, 33 cents; and of the full-feed steers, 41 cents per head per week. In Period 3, when the ration consisted of one part of clover hay and five parts of ground corn, the fertilizing elements in the manure of the maintenance steers would have cost 12 cents; of the one-third-feed steers, 21 cents; of the two-thirds-feed steers, 28 cents; and of the full-feed steers, 29 cents, per head per week. In Period 4, when the ration consisted of one part of clover hay, four parts of corn, and one part of linseed meal, the fertilizing elements in the manure of the maintenance steers would have cost 20 cents; of the one-third-feed steers, 30 cents; of the two-thirds-feed steers, 40 cents; and of the full-feed steers, 47 cents per head per week. In Period 5, on the same ration as in Period 4, the fertilizing elements in the manure from Steer 650 (on full feed) would have cost 39 cents; of Steer 656 (on maintenance), 19 cents; of Steer 666 (on full feed), 48 cents; of Steer 669 (on one-third feed), 33 cents; of Steer 652 (on full feed), 46 cents; of Steer 665 (on two-thirds feed), 46 cents; and of Steer 661 (on full feed), 56 cents per week. In this connection, it should be noted that these figures do not include the values of the organic matter of the manures.

These figures will give the stock-feeder some idea, at least, as to the value of the manure produced by two-year-old steers under similar conditions.

It is also of interest to compare the commercial value of the manure produced by the two-year-old steers with the cost of the feed consumed. Table 26 has been calculated upon this basis, corn being valued at 56 cents a bushel, clover hay at $10 per ton, linseed meal at $40 per ton, nitrogen at 15 cents per pound, phosphorus at 10 cents per pound, and potassium at 6 cents per pound. While these valuations do not represent the market prices of either the feeds used or of the fertilizing elements at the time of the publication of this bulletin, yet they are comparable with each other and represent average prices under ordinary conditions.

It is clear from the data in Table 26 that no inconsiderable part of the cost of the feed is returned in the manure. In Period 1, the commercial value of the manure represented 35.77 percent of the cost of the feed consumed; in Period 2, 26.66 percent; in Period 3, 23.89 percent; in Period 4, 31.58 percent; in Period 5, 28.52 percent; and during the entire experiment, 29.39 percent. Of course, this does not take into consideration any losses in handling the manure from the time it is excreted until it is applied to the soil. While these losses may be considerable, yet such is not necessarily the case. On the other hand, these figures do not assign any value to the organic matter of the manure. It is possible, or even probable, that the value of the organic matter would more than offset the losses of nitrogen, phosphorus, and potassium in handling the manure. In any case, the fact remains that the manure does have a considerable value which is not often taken into consideration in figuring the financial balance in cattle-feeding operations.

SUMMARY

1. Eight two-year-old, choice feeder steers were divided into four lots of two steers each. One lot was given a ration slightly above maintenance; another, as much feed as the steers would eat readily; another, an amount of feed equal to the maintenance ration plus one-third of the difference between the maintenance and the full-feed ration; and another, an amount equal to the maintenance ration plus two-thirds of the difference between the maintenance and the full-feed ration.

2. The experiment lasted for thirty-seven weeks and was divided into five test periods. The first period was five weeks in length, the second, third, and fourth were each six weeks in length, and the fifth was four weeks in length.

3. The feeds used were clover hay, ground corn, and linseed oil meal. The ration of the first test period consisted of clover hay and ground corn in the ratio of 1 to 1; that of the second, of clover hay and ground corn in the ratio of 1 to 3; that of the third, of clover hay and ground corn in the ratio of 1 to 5; and that of the fourth and fifth, of clover hay, ground corn, and linseed oil meal in the ratio of 1 to 4 to 1.

4. The consumption of organic matter, nitrogen, and phosphorus, the excretion of organic matter in the feces, the excretion of nitrogen

TABLE 27.—SUMMARY OF THE AVERAGE EXCRETION OF ORGANIC MATTER, NITROGEN, AND PHOSPHORUS

(Results expressed in percent of the amount consumed)

Period	Weeks	Ratio of hay to corn to linseed meal	Organic matter in feces	Nitrogen in feces and urine	Phosphorus in feces[1]
1	1–5	1:1:0	33.20	81.82	92.77
2	8–13	1:3:0	27.89	86.53	95.81
3	17–22	1:5:0	24.24	86.72	84.92
4	25–30	1:4:1	21.85	89.97	80.61
5	34–37	1:4:1	22.75	92.56	80.82
Total......	1–37	....	26.24	87.40	86.51

[1] Omitting Steer 656.

in the feces and urine, and the excretion of phosphorus in the feces and in the urine (for thirteen weeks only) were determined.

5. In Period 1, on a ration consisting of clover hay and ground corn in equal parts, 33 percent of the organic matter was recovered in the manure; in Period 2, on a ration consisting of 1 part clover hay and 3 parts ground corn, 28 percent was recovered; in Period 3, when the ration consisted of 1 part clover hay and 5 parts ground corn, 24 percent was recovered; in Periods 4 and 5, when the ration consisted of 1 part clover hay, 4 parts ground corn, and 1 part linseed meal, 22 percent and 23 percent, respectively, were recovered; during the entire experiment of thirty-seven weeks, 26 percent was recovered.

6. The amount of feed consumed had no influence upon the percentage of organic matter excreted, except in Period 1, and possibly in Period 2.

7. Slightly more organic matter was recovered in the manure than would have been recovered in a system of farming in which the corn is sold and the clover plowed under.

8. In Period 1, 82 percent of the nitrogen consumed was excreted, 69 percent of it being in the feces and 31 percent in the urine; in Period 2, 87 percent was excreted, 59 percent in the feces and 41 percent in the urine; in Period 3, 87 percent was excreted, 56 percent in the feces and 44 percent in the urine; in Period 4, 90 percent was excreted, 36 percent in the feces and 64 percent in the urine; in Period 5, 93 percent was excreted, 35 percent in the feces and 65 percent in the urine; during the entire experiment of thirty-seven weeks, 87 percent was excreted, 50 percent in the feces and 50 percent in the urine.

9. The amount of feed consumed had no influence upon the percentage of nitrogen excreted.

10. When linseed meal was introduced into the ration, the nitrogen balance of the soil was more than maintained, 160 percent as much nitrogen being excreted as was contained in the farm-grown feeds.

11. The nitrogen recovered in the manure averaged 326 percent of that which would have been recovered in a system of farming in which the corn is sold and the clover plowed under. In Period 1, the proportion was 131 percent; in Period 2, 260 percent; in Period 3, 391 percent; in Period 4, 702 percent; in Period 5, 680 percent.

12. In Period 1, 93 percent of the phosphorus consumed was excreted; in Period 2, 96 percent; in Period 3, 85 percent; in Period 4, 81 percent; in Period 5, 81 percent; and during the entire experiment, 87 percent. Practically all of the excreted phosphorus was in the feces, except in the case of one steer.

13. The amount of feed consumed had no influence upon the percentage of phosphorus excreted.

14. When linseed meal was introduced into the ration, the phosphorus balance of the soil was more than maintained, 141 percent as

much phosphorus being excreted as was contained in the farm-grown feeds.

15. The phosphorus recovered in the manure averaged 521 percent of that which would have been recovered in a system of farming in which the corn is sold and the clover plowed under. In Period 1, the proportion was 225 percent; in Period 2, 550 percent; in Period 3, 934 percent; in Period 4, 1,244 percent; and in Period 5, 1,067 percent.

16. Assuming that nitrogen costs 15 cents per pound, phosphorus 10 cents, and potassium 6 cents, if purchased in commercial fertilizers, the values of these elements excreted per head per week were as follows:

Period	Maintenance lot	One-third-feed lot	Two-thirds-feed lot	Full-feed lot
1	$0.20	$0.29	$0.38	$0.45
2	0.15	0.24	0.33	0.41
3	0.12	0.21	0.28	0.29
4	0.20	0.30	0.40	0.47
5	0.29	0.40	0.46	0.56
Total	$0.18	$0.28	$0.37	$0.40

17. The value of the manure varied directly with the amount of feed consumed. It also varied with the character of the ration, being greater the larger the proportion of clover hay in the ration, and greatest when linseed oil meal was introduced into the ration.

18. At the values assumed for fertilizing elements, no inconsiderable part of the cost of the feed was returned in the manure. In Period 1, the commercial value of the manure was 36 percent of the cost of the feed; in Period 2, 27 percent; in Period 3, 24 percent; in Period 4, 32 percent; in Period 5, 29 percent; and in the entire experiment, 29 percent.

CONCLUSIONS

1. By feeding two-year-old steers on clover hay and corn, and carefully conserving the resulting manure, it is possible to return to the soil one-fourth to one-third of the organic matter of the ration and three-fourths to four-fifths of the nitrogen and phosphorous of the ration.

2. It is possible to maintain, or even to increase, the nitrogen and phosphorus content of the soil by adding to the ration a nitrogenous supplement such as linseed or cottonseed meal.

3. When a three-year rotation is practiced (e. g., corn, oats, and clover), approximately two-thirds as much organic matter can be returned to the land by feeding two-year-old cattle and returning the

manure to the soil as can be returned in a system of farming in which the corn is sold and the clover plowed under. In a four- or five-year rotation, corn appearing twice (e. g., corn, corn, oats, and clover; or corn, corn, oats, clover, and wheat), as much organic matter can be returned by feeding the corn and clover as by selling the corn and plowing under the clover.

4. In the three-year rotation above mentioned, slightly more nitrogen can be returned by feeding the corn and clover than by selling the corn and plowing under the clover. In the four- and five-year rotations, about twice as much nitrogen can be returned.

5. In the three-year rotation, approximately twice as much phosphorus can be returned by feeding the corn and clover as by selling the corn and plowing under the clover. In the four- and five-year rotations, four or five times as much can be returned.

The authors wish to acknowledge the efficient assistance rendered by J. J. Yoke and W. H. Balis in the feeding, weighing, and care of the animals; by F. W. Gill in the analytical work; and by P. A. Hoffman, W. J. Gage, Jr., and W. A. Hixson in the weighing and sampling of the feeds, orts, feces, and urine and in the keeping of many of the records.

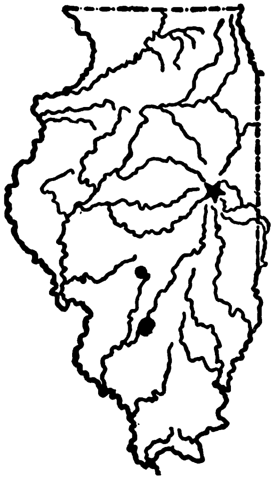
UNIVERSITY OF ILLINOIS

Agricultural Experiment Station

BULLETIN No. 210

FIELD INVESTIGATIONS OF FORAGE POISONING IN CATTLE AND HORSES

H. P. RUSK AND H. S. GRINDLEY



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Summary of Bulletin No. 210

Feeding Tests with Corn Silage Suspected of Causing Forage Poisoning in Cattle.—Numerous outbreaks of forage poisoning in cattle, horses, and mules have been reported to the University, but attempts to reproduce the disease experimentally in cattle by feeding suspected or contaminated feeds have been unsuccessful.

The results of these investigations seem to indicate that most cattle are not so susceptible to forage poisoning as are horses and mules, and that contaminated corn silage, and possibly other animal feeds which are unsafe or fatal to horses, may be fed with less danger to cattle. Evidence from many outbreaks leads to the suggestion that some cattle may be more susceptible than others, and that damaged or otherwise contaminated corn silage, and possibly other feeds, may in some instances produce fatal results in cattle following ingestion. **Pages 163-169.**

Report of Forage Poisoning Investigations with Horses at Ottawa, Illinois.—Contaminated corn silage from the McLean silo near Ottawa, Illinois, induced a fatal type of forage poisoning in horses following ingestion. The most obvious and characteristic symptoms exhibited by the horses affected in this experiment were paralysis of the throat, profuse salivation, and lack of muscular coordination.

Prophylactic doses of Botulinus antitoxin and related immune sera, developed by Drs. Graham, Brueckner, and Pontius at the University of Kentucky, protected experimental horses against the effect of the daily ingestion of contaminated corn silage responsible for the McLean outbreak. The results of the two tests at the McLean farm apparently justify a trial of these sera in cases of similar outbreaks. **Pages 169–176.**

Note.—These investigations were completed before the Division of Animal Pathology was established. They were continued by Dr. Robert Graham, Chief in Animal Pathology. All communications relating to forage poisoning should be addressed to the above division.

FIELD INVESTIGATIONS OF FORAGE POISONING IN CATTLE AND HORSES

By H. P. RUSK, Assistant Chief in Cattle Husbandry, and
H. S. GRINDLEY, Chief in Animal Nutrition

During recent years an increasing number of inquiries relative to forage poisoning have been received by the Department of Animal Husbandry at the University of Illinois. Many of these inquiries regarding outbreaks in herds of cattle mentioned corn silage as a suspected feed. While this department did not attempt to give any authoritative opinion on such cases, it was freely conceded that our experience would not lead us to suspect corn silage as the source of trouble in outbreaks of forage poisoning among cattle. Common molds found on silage are often suspected of having pathogenic properties, but specific evidence to warrant such suspicion is wanting. It is common knowledge that in most cattle-feeding plants where corn silage is used extensively, cattle often receive some more or less moldy silage, and in many cases are allowed to pick over with impunity the refuse from the tops of newly-opened silos. Certainly the number of outbreaks of this disease in cattle is irrelative to the primary occurrence of molds upon animal feeds.

FEEDING TESTS WITH CORN SILAGE SUSPECTED OF CAUSING FORAGE POISONING IN CATTLE

The series of investigations reported herein was started at the University after an outbreak of forage poisoning had occurred among twenty experimental calves during the winter of 1915-16. These calves consisted of steers and heifers, coming yearlings that were being fed in two lots of ten each in a test (known as Experimental Project 229) to determine the relative efficiency of feeding grain according to appetite and in feeding it in restricted amounts with silage as the sole roughage. The plan of this experiment was to feed each of the two lots the following rations. Lot 1: shelled corn 5 parts, and cottonseed meal 1 part, according to appetite; silage to be fed in such amounts as would not restrict the calves' appetite for concentrates. Lot 2 was to receive the same grain mixture as Lot 1, but the amount was to be restricted to that barely necessary to obtain satisfactory gains; corn silage to be fed *ad libitum* to this lot.

For some time prior to the first of January, 1916, it had been evident that a few calves in each lot were doing poorly. They were unthrifty in appearance, ate very sparingly, and made unsatisfactory gains. On December 16, No. 35, a calf in Lot 1, was found dead about two hours after the lot received its morning feed. It was thought that she had slipped on the sleety pavement and broken her neck, as her head was doubled back under her body. Even in the light of subsequent developments, it appears unlikely, altho possible, that death may have occurred during convulsions accompanying an attack of forage poisoning. On January 26, No. 38, a Hereford heifer in Lot 2, died in a tonic spasm, which undoubtedly was due to forage poisoning. Unlike Calf No. 35, No. 38 had shown symptoms of unthriftiness for at least a month previous to death. During this time she had been more or less stiff and her appetite was poor. The stiffness gradually increased until the evening of the 25th. She was down on the morning of January 26, and convulsions preceded death about noon.

During the month of January, seven calves were observed to be very unthrifty, showing marked stiffness in moving, loss of appetite, and a falling off of gains. When these unthrifty animals were excited, as would happen on weigh days or when the men were cleaning the manure from the lots, the stiffness seemed to be aggravated, their eyes became starey, and they exhibited a terrified appearance. Several times on such occasions, individual calves were suddenly seized with tonic convulsions, followed by complete loss of locomotion. A calf thus affected would stand for a moment or two with fore feet wide apart as if trying to brace itself, mouth open, tongue slightly extended as if about to cough, and then gradually lean backward until it fell to the ground and lay broadside with feet extended, presenting an appearance resembling death rigor. This condition would last from a few seconds to a few minutes, when the calf would relax, slowly revive, and assume a normal attitude. These nervous manifestations, involving the voluntary muscles, were accompanied by profuse salivation, a lateral movement of the jaws, and difficulty in breathing. These unthrifty calves, when excited, would often show evidence of impaired vision by running or walking into fences, against the feed bunks, or against other calves in the lot, without falling or suffering from tonic spasms. While in this condition, they would show extreme stiffness, muscular tremors in the limbs, and general nervousness.

On March 11, it was so evident that the object of the experiment could never be realized because of the unthriftiness and nervous derangement of so many of the calves, that it was decided to abandon the project and use the calves in an attempt to determine whether any of the feeds were responsible for the abnormal condition described. This test (known as Project 229a) was conducted according to the following plan.

TEST AT ILLINOIS EXPERIMENT STATION TO DETERMINE FEEDS RESPONSIBLE FOR UNTHRIFTINESS OF CALVES

Plan.—Six normal and six abnormal calves were selected from the animals used in Project 229 and divided into six lots; each lot contained one thrifty and one unthrifty animal. The rations fed to the respective lots consisted of the feeds indicated by the following tabulation and in addition 5 parts of shelled corn:

Lot 1	Cottonseed meal 1 part, silage 6 parts
Lot 2	Cottonseed meal 1 part, alfalfa hay
Lot 3	Linseed oil meal 1 part, silage 6 parts
Lot 4	Linseed oil meal 1 part, moldy silage 6 parts
Lot 5	Cottonseed meal 2 parts, silage 7 parts
Lot 6	Cottonseed meal 2 parts, alfalfa hay

Method of Feeding.—All animals were fed individually in stalls. Those receiving silage had the grain and silage thoroly mixed together before feeding. Hay was fed in the same manger as the grain but not mixed with it. All refused feed was weighed back before the following feed was given. All cattle were fed according to appetite.

Equipment.—Two units of the old cattle-feeding plant were used. This plant consists of a long, low shed 12 feet deep and open on the south. Each unit is 36 feet long and opens on a 36x48-foot paved lot. One-half of each of these two units was divided into six stalls, in which the calves were fed individually. The calves were confined in the stalls at feeding time by means of a heavy chain hooked across the rear of each stall. Approximately two hours after feeding, the calves were turned out of the stalls and allowed to run together in the remaining half of the shed and pen. Lots 1, 2, and 3 were kept in the east unit and Lots 4, 5, and 6, in the unit next to the west.

Cattle:

	Calf No.	Weight	Previous treatment
		lbs.	
Lot 1	40	885	Light grain ration
	23	665	Heavy grain ration
Lot 2	6	725	Light grain ration
	36	465	Light grain ration
Lot 3	28	825	Heavy grain ration
	8	575	Heavy grain ration
Lot 4	11	795	Heavy grain ration
	27	645	Heavy grain ration
Lot 5	21	745	Light grain ration
	39	635	Heavy grain ration
Lot 6	13	790	Heavy grain ration
	34	595	Heavy grain ration

This experiment was started on March 11, 1916, and concluded July 8, 1916.

A study of the foregoing outline will show that an attempt was made to determine by a process of elimination the feed responsible for the condition described. Lot 1 received the same feed mixture that was fed in Project 229. In Lot 2, alfalfa was substituted for corn silage. In Lot 3, linseed oil meal was substituted for cottonseed meal, the roughage remaining unchanged. In Lot 4, the cottonseed meal was replaced by linseed oil meal and the roughage consisted exclusively of moldy silage. Lot 5 received a double allowance of cottonseed meal with silage as the roughage. Lot 6 received a double allowance of cottonseed meal with alfalfa as the roughage. It was felt that if the unthrifty condition was due to the accumulative effect of long-continued feeding of cottonseed meal, Lots 1, 2, 5, and 6 might provide some positive evidence on this point, and Lot 3, and possibly Lot 4, might be expected to give negative results. If the silage were primarily involved, then Lots 1, 3, 4, and 5 might give positive results, and the remaining lots negative results. If it were moldy silage, then Lot 4 might be expected to give positive results, and Lots 2 and 6 negative results. It may be significant that the calves were bedded with straw during the progress of Project 229, while shavings were used for bedding in the forage-poisoning test. A general summary of the results from March 11 to July 8 is contained in Table 1.

A study of this table shows that in no case did a calf that was unthrifty at the beginning of the test consume as much feed as any one of the calves that was thrifty when the test was started.

Considering the length of time that these cattle had been on feed when this test was started, and the season of the year during which it was conducted, the gains made by the calves that were thrifty at the start were entirely satisfactory, with the possible exception of the gains made by No. 11, a heifer that received spoiled silage as her sole roughage. However, this heifer could not have been considered unthrifty in spite of the fact that she gained only .76 pound per day. She carried a good finish and was in excellent thrift, as shown by her general appearance at the end of the test. In fact, there was a general improvement in every animal, with the possible exception of No. 27. This steer suffered from malnutrition during the test and his joints were badly swollen at times, but even he was not at his worst at the close of the experiment, and at no time during the test did he show symptoms suggestive or diagnostic of forage poisoning such as were exhibited by this and other calves before the trial was inaugurated.

The data collected in this test and the reaction of these calves to the rations used do not warrant any conclusion regarding the identity of the feed harboring the causative agent of disturbances observed in these calves during the progress of Project 229.

TABLE 1.—FEED CONSUMPTION AND GAINS IN TEST TO DETERMINE THE FEED RESPONSIBLE FOR UNTHRIFTINESS OF CALVES (PROJECT 229a)
March 11—July 8, 1916

	Calf No.	Feeds	Total feed consumed	Daily feed	Total gain	Daily gain
			lbs.	*lbs.*	*lbs.*	*lbs.*
Lot 1	40	Corn	1469.75	12.34	225	1.89
		C. S. M.	294.50	2.47		
		Silage	1767.35	14.85		
	33	Corn	920.16	7.73	140	1.18
		C. S. M.	181.89	1.53		
		Silage	1101.45	9.26		
Lot 2	6	Corn	1481.60	12.45	220	1.85
		C. S. M.	297.40	2.50		
		Alfalfa	349.90	2.94		
	36	Corn	846.83	7.12	105	0.88
		C. S. M.	170.27	1.43		
		Alfalfa	170.05	1.43		
Lot 3	28	Corn	1152.90	9.70	165	1.39
		Oil meal	231.50	1.95		
		Silage	1390.90	11.69		
	8	Corn	677.75	5.69	85	0.71
		Oil meal	135.75	1.14		
		Silage	755.95	6.38		
Lot 4	11	Corn	1085.80	9.12	90	0.76
		Oil meal	218.15	1.83		
		Bad silage	1237.30	10.40		
	27	Corn	792.20	6.65	40	0.34
		Oil meal	159.35	1.34		
		Bad silage	871.65	7.28		
Lot 5	21	Corn	1224.10	10.29	245	2.06
		C. S. M.	496.15	4.17		
		Silage	1712.38	14.39		
	39	Corn	859.72	7.22	165	1.39
		C. S. M.	342.43	2.88		
		Silage	1194.50	10.04		
Lot 6	13	Corn	1219.75	10.25	190	1.60
		C. S. M.	487.85	4.10		
		Alfalfa	399.45	3.36		
	34	Corn	803.36	6.75	125	1.05
		C. S. M.	319.14	2.68		
		Alfalfa	199.07	1.67		

A Feeding Test with Suspected Silage at Harristown, Illinois

Shortly after the foregoing project was started, Charles Ash, of Harristown, Illinois, notified the University of the loss of several coming yearling pure-bred Herefords and a few older cattle from illness resembling forage poisoning. Here again, silage was the suspected feed. Upon the request of Mr. Ash, representatives from the University visited the farm and examined the silage and other feeds used. A preliminary examination of the feeds revealed nothing that might be suspected except a very little mold in small areas in the silo. The silage, as a whole, was judged to be good.

With the cooperation of Mr. Ash, it was decided to conduct a test upon his farm supplementary to the one under way at the University. This test was conducted according to the following outline:

Plan.—One lot of five choice yearling steers and one lot of plain bull calves were fed a ration of the suspected corn silage, linseed oil meal, and water.

Cattle.—Five choice Hereford yearling steers were purchased from Mr. Ash, and five pure-bred Holstein bull calves dropped the preceding fall were purchased from the Dairy Department, University of Illinois. The calves had been used on a milk-substitute experiment and did not show the thrift and bloom that the yearlings possessed. The average initial weight of the Herefords was 675 pounds, and the average initial weight of the calves was 242 pounds.

TABLE 2.—FEEDING TEST WITH SUSPECTED SILAGE AT HARRISTOWN, ILLINOIS

Initial date (1916)	Final date	Days	Total initial weight	Final weight	Gain	Ave. daily gain	Silage	Oil meal
Lot 1—Holstein Calves								
			lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
May 10	May 24	14	1210	1290	80	1.14	1060	26.50
May 24	June 28	35	1290	1490	200	1.14	3130	78.25
June 28	July 5	7	1490	1480	-10	(—)	660	16.50
July 5	July 19	14	1480	1525	45	.643	2010	50.25
Lot 2—Hereford Yearlings								
May 10	May 24	13½	3375	3520	145	2.14	1966.20	49.30
May 24	June 28	35	3520	3915	395	2.25	6694.63	167.37
June 28	July 5	7	2915	3900	-15	(—)	1400.00	35.00
July 5	July 19	14	3900	3970	70	1.0	2910.00	72.75

All of the cattle made satisfactory gains; in fact, the Herefords yielded a profit on the operation after all expenses were deducted. The Holstein calves were not as thrifty at the start and did not make as satisfactory gains as the Herefords.

During the late summer of 1916, a further test was made at Ottawa, Illinois. In this test three two-year-old steers, one cow, and two sucking calves were fed corn silage which had been experimentally proved capable of inducing a fatal type of forage poisoning when consumed by horses. One calf died during the experiment, but death was attributed to causes other than forage poisoning. As in the other field tests with cattle, typical symptoms of forage poisoning were not produced by the experimental ration.

The results of these investigations seem to indicate that most cattle are not so susceptible to forage poisoning as are horses and mules, and that contaminated corn silage, and possibly other animal feeds which are unsafe or fatal to horses, may be fed with less danger to cattle. This deduction is in accord with the observations of Graham, Brueckner, and Pontius, in a remote outbreak of forage poisoning,[1] where the disease was produced in a horse and the cattle appeared to be non-affected. However, the evidence from many outbreaks leads the authors to suspect that some cattle are more susceptible than others and that damaged or otherwise contaminated corn silage, or possibly other feeds, may in some instances produce fatal results in cattle following ingestion.

REPORT OF FORAGE POISONING INVESTIGATIONS WITH HORSES AT OTTAWA, ILLINOIS

During the month of June, 1916, an outbreak of forage poisoning occurred among horses on the farm of Alexander McLean, near Ottawa, Illinois. This disease was reported to the University by Mr. I. S. Brooks, County Adviser for LaSalle county. Upon investigation, it was learned that Mr. McLean had fed silage to his horses during the late winter and spring months but had discontinued the use of silage during the early part of the summer while the pastures were good. Some time in June, after the pastures began to fail, the silo was reopened, and the feeding of silage to both horses and cattle was resumed. Some of the spoiled silage removed from the silo when it was reopened, was used as bedding for both horses and cattle. Within three or four days after the use of silage was resumed, symptoms of forage poisoning were observed in certain of the horses and two mules. Eight or nine head of horses in all were affected and six died. Dr. Fowlie, the local veterinarian who attended these cases, described the symptoms as typical of forage poisoning. An inspection of the feeds used and the history of the outbreak led the authors strongly to suspect silage as the contaminated feed, but the evidence was not conclusive, as cattle receiving feed from the same silo had shown no symptoms of the disease and some of the other feeds which had been fed to the horses were not entirely free from molds; hence it was decided to attempt to secure some positive evidence in regard to the role silage played in this outbreak.

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[1] Ky. Exp. Sta. Bul. 208.

Five horses were purchased in the vicinity of Ottawa and put on a ration of the suspected silage, wholesome corn, and water, at the McLean farm on June 28, 1916. One horse began to show symptoms of forage poisoning on the third day and died on the fourth. Another went down on July 2 and died on July 4. Another was killed on July 8, after showing pharyngeal paralysis for four days and consuming no feed or water for that length of time. The two remaining horses survived considerably longer, but all five were dead by the end of the third week. One of Mr. McLean's horses was used as a control and fed corn from the same source as that used in the test, with negative results.

The symptoms of forage poisoning, as exhibited by the horses affected in these tests, were uniform and pronounced. The most characteristic symptom was paralysis of the throat. One of the first manifestations of the disease was the inability of the affected horse to drink. Prolonged efforts were made to drink but to no avail. This condition is often overlooked where horses obtain their water from tanks so large that it is difficult or impossible to tell whether or not the water has actually been lowered. In fact, under such conditions, the observer may get the impression that the horse is drinking abnormally large amounts when in reality he is swallowing very little or none. However, when allowed access to water in a bucket, affected animals made prolonged efforts to drink without perceptibly lowering the water. Some were able to eat from one to three or four days after they were unable to drink. Our observations were that affected animals soon became unable to swallow feed as well as water. The appetites remained normal. Many of the horses continued to masticate feed as long as they could stand, but this masticated feed mixed with saliva dribbled from their mouths, due to their inability to swallow. The other characteristic symptoms were profuse salivation and lack of muscular coordination. In the opinion of those connected with this feeding test, the results clearly established the fact that the silage was the source of the poisoning. An autopsy was held on each horse and bacteriological cultures were made from various organs of all the horses as well as from the feed.

Three steers, a cow, and two calves, were fed experimentally for several weeks on a ration composed exclusively of this silage and water, without producing any noticeable symptoms of forage poisoning. These results correspond with the previous experience of the authors in trying to induce the disease in cattle, reported in the first part of this bulletin; and taken in conjunction with results of previous tests they indicate that cattle are much less susceptible to the disease than are horses. However, the history of several outbreaks of an apparently similar disease among cattle leads to a strong belief that contaminated silage may sometimes cause forage poisoning in this class of animals.

At the University of Illinois, the bacteriological examination of the feed, as well as the cultures made from the organs of the dead horses, failed to reveal any organism that could be considered the causative agent of forage poisoning. However, Dr. Robert Graham, formerly of the University of Kentucky but now connected with the University of Illinois, whose services had been secured in an advisory capacity on this project, took samples of the silage to his laboratory at the Kentucky Experiment Station, where he was able to isolate an organism corresponding very closely to one he had isolated from an oat hay which had been proved to be the source of an outbreak of forage poisoning in Kentucky. Graham, Brueckner, and Pontius, working at the University of Kentucky independently of Rusk and Grindley, developed a serum that in laboratory tests protected against fatal doses of broth cultures of the organisms isolated from both of these sources, as well as from similar organisms isolated from other animal feeds.

In the meantime, the University of Illinois purchased the silage remaining in the McLean silo with the understanding that the silo would be refilled and as soon as it was fed down to the point where the contaminated silage commenced, the University would be given an opportunity to conduct further experiments. A circular oilcloth cover made to fit the silo marked the division between the new and the old silage. When this point in the silo was reached, arrangements were made to give the serum mentioned a field trial against the McLean silage. Accordingly, on June 13, 1917, eight horses that had been purchased on the Chicago market, were started on a ration of this silage, wholesome corn, and water. Five of these horses received intravenous injections of the Botulinus antitoxin and three were left as controls without serum. The summary of this test is shown in Table 3.

TABLE 3.—SECOND FEEDING TRIAL WITH HORSES AT THE McLEAN FARM
June 13—July 12, 1917

Horse No.	Serum	Silage fed	Silage refused	Silage consumed	Silage consumed per day	Days without feed	Days without water	Date died
		lbs.	*lbs.*	*lbs.*	*lbs.*			
1	*None*	445.5	136.75	308.75	22.87	6.5	10.0	July 3
2	Serum	996.5	366.0	630.5	21.02	None	None	
3	Serum	523.5	294.5	229.0	16.96	8.5	1.0	July 5
4	Serum	835.5	406.5	409.0	13.63	None	None	
5	*None*	287.5	101.0	186.5	26.64	2.5	3.5	June 22
6	Serum	1188.0	477.5	710.5	23.68	None	None	
7	Serum	1308.5	336.0	972.5	32.41	None	None	
8	*None*	247.0	78.5	168.5	21.06	4.0	4.0	June 23

In this table no account is taken of the corn fed, as the horses received a uniform amount of 6 pounds of ear corn per head per day, and practically none was refused. The consumption of silage varied a great deal with individuals, ranging from 13.63 pounds per day in the case of No. 4 to 32.41 pounds per day for No. 7. It will be noticed from the foregoing tabulation that all of the control horses died in from 9½ to 20 days after the beginning of the experiment. All of the serum horses came thru in excellent condition except No. 3, a horse that was clearly off from the second day of the experiment. On that day, Dr. Fowlie, of Ottawa, who gave this test a great deal of his personal attention, stated that in his opinion this horse had been "drugged" before he left the Chicago yards, and that he was suffering from an overdose. At different times during the test, this horse showed symptoms of colic, a condition not observed in any of the horses suffering from forage poisoning. Dr. Fowlie, on two or three occasions, gave this horse purgatives with indifferent results. From June 26 until he died, this horse ate little or no feed. During this time, he received 141 pounds of silage and refused all but 9 pounds. This difference of 9 pounds was probably due as much to error in weighing and drying out of the silage as to actual consumption by the horse. He died on July 5, and upon post-mortem examination it was found that his caecum was ruptured, accompanied by diffuse peritonitis. His death was thought not to be due in any way to forage poisoning.

While the foregoing table makes no mention of the fact, the feed records taken contain a complete record of water drunk and of temperatures taken twice daily. A study of these temperature data did

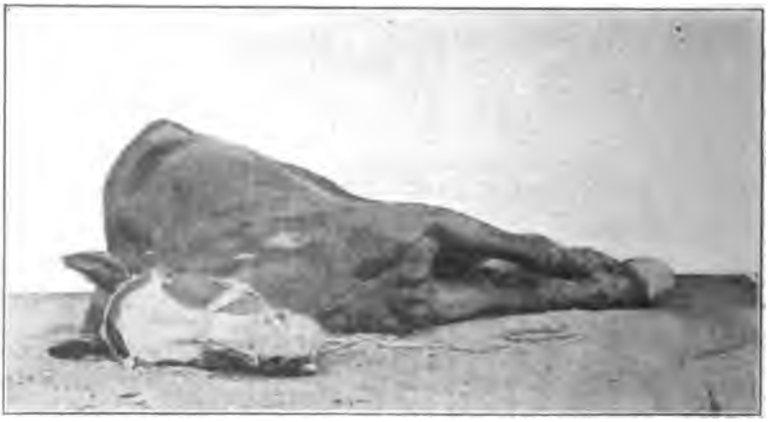

FIG. 1.—HORSE NO. 9 JUST BEFORE DEATH. NOTE PENDULANT CONDITION OF THE TONGUE, DUE TO PARALYSIS

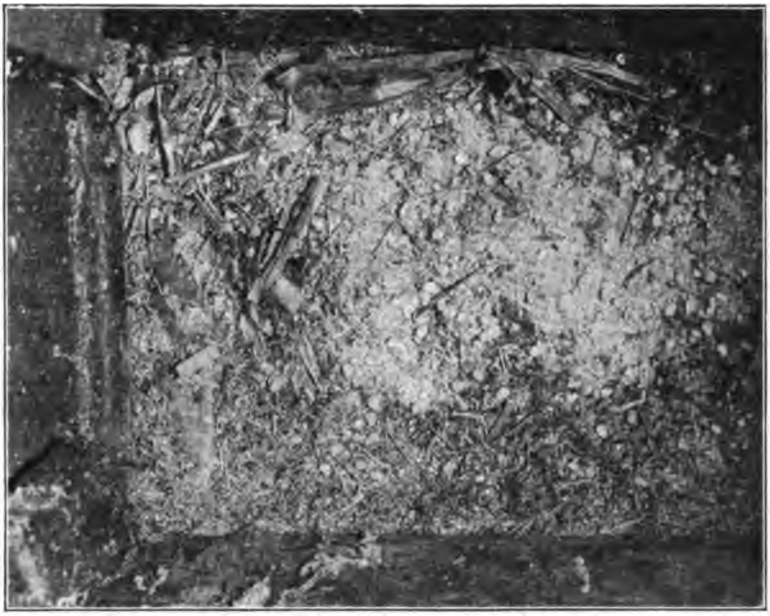

FIG. 2.—BOTTOM OF MANGER OF HORSE NO. 5, SHOWING PARTLY MASTICATED FEED MIXED WITH SALIVA, WHICH HAD DRIBBLED FROM HIS MOUTH

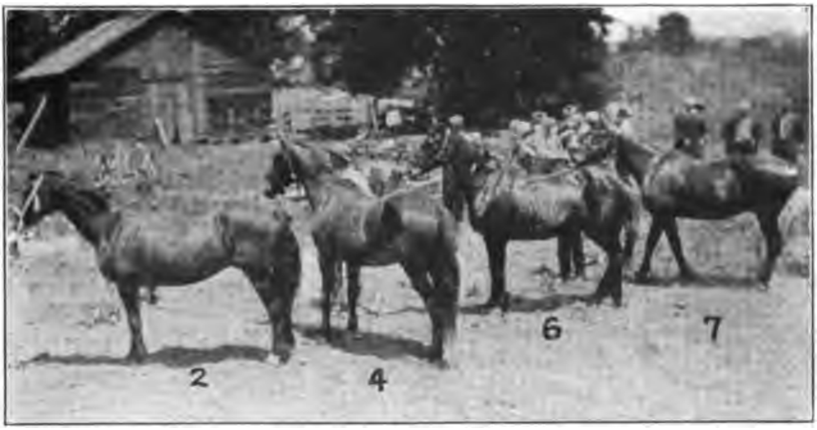

FIG. 3.—HORSES NOS. 2, 4, 6, AND 7, ON JULY 12, 1917

not reveal any characteristic or consistent fluctuation from the normal and the data therefore were not tabulated.

Horses Nos. 6 and 7 were worked regularly during the last few days of the test, in order to determine whether or not this ration was sufficient to maintain them at hard work. Each horse was hitched with one of Mr. McLean's and given a full day's work in cultivating corn. No. 6 gave an unplanned-for exhibition of her superabundant energy on the second day that she was worked by taking the leading part in a spirited runaway.

To make a further and more comprehensive study of the prophylactic properties of the immune sera, another test was started on June 24 with ten head of horses. These horses received nothing but contaminated corn silage and water, no corn being fed and no bedding used. The serum treatment of these horses is shown in Table 4 and a summary of the feeds eaten and the gains made are shown in Table 5.

TABLE 4.—SERUM TREATMENT OF HORSES IN THIRD FEEDING TRIAL AT McLEAN FARM
June 24—July 12, 1917

Horse No. and treatment	June 24, 2:30 p. m.	July 3	July 5	July 6	
9—*None*	....	....	....	....	***Died***
10—G. M.	40 cc. intra.	40 cc. sub.	40 cc. sub.	....	Lived
11—S. G.	40 cc. intra.	40 cc. sub.	....	....	Lived
12—S. G.	40 cc. intra.	....	....	....	Lived
13—G. M.	40 cc. intra.	40 cc. sub.	40 cc. sub.	....	Lived
14—G. M.	40 cc. intra.	....	....	....	Lived
15—H. O.	40 cc. intra.	....	....	40 cc. intra.	Lived
16—H. O.	40 cc. intra.	....	....	....	Lived
17—H-91	40 cc. intra.	....	....	40 cc. intra.	Lived
18—H-91	40 cc. intra.	....	....	....	Lived

G. M.=Goat serum immune to pathogenic bacillus isolated from McLean silage.
S. G.=Sheep serum immune to pathogenic bacillus isolated from Gaines silage.
H. O.=Horse serum immune to pathogenic bacillus isolated from Griffith oat water.
H-91=Horse serum immune to pathogenic bacillus isolated from cecum of Horse 91.

TABLE 5.—SUMMARY OF DATA FROM THIRD FEEDING TRIAL WITH HORSES AT THE McLEAN FARM

June 24—July 12, 1917

Horse No.	Serum	Silage fed	Silage refused	Silage cunsumed	Silage consumed per day	Initial weight	Final weight	Gain (+) or loss (—)
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
9	*None*	819.0	75.0	744.0	46.50	1125	...	*Died*[1]
10	Serum	578.0	119.5	458.5	25.47	875	830	—45
11	"	726.0	53.0	673.0	37.39	1150	1120	—30
12	"	651.5	123.5	528.0	29.33	1050	1010	—40
13	"	692.5	99.0	593.5	32.97	1025	975	—50
14	"	650.5	113.5	596.0	33.11	875	830	—45
15	"	697.0	75.0	602.0	33.44	825	815	—10
16	"	713.5	37.0	676.5	37.58	1080	1125	+45
17	"	731.0	54.5	676.5	37.58	1100	1090	—10
18	"	685.0	77.5	607.5	33.75	950	930	—20

[1] No. 9 died July 12, having lived two days without water and feed.

It will be noted that all but one of these horses received serum. This horse developed typical symptoms of forage poisoning and died on July 12. None of the other horses at any time exhibited symptoms of forage poisoning. They were continued on this ration until after the morning feed on Sunday, July 15, at which time the silage was practically gone and its use had to be abandoned. While only one of these horses maintained his weight on a ration of corn silage and water, the losses were not significant, and in all probability most of these horses would have regained their initial weight if the experiment could have been continued a month longer.

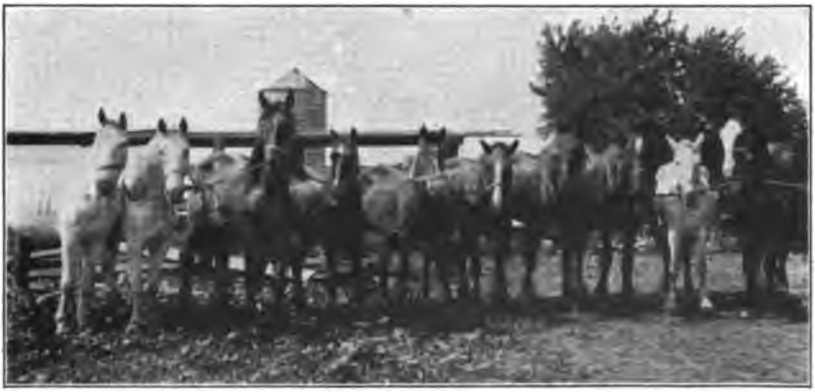

FIG. 4.—HORSES IN THIRD FEEDING TRIAL AT McLEAN FARM. NOS. 9 TO 18, FROM RIGHT TO LEFT

The results of these two tests at the McLean farm lead the authors to believe that these sera protected the horses against forage poisoning caused by the organism responsible for the McLean outbreak. Of course it is not contended that all outbreaks of forage poisoning among horses are caused by this or similar organisms, but the results of this experiment apparently justify a trial of this serum in cases of similar outbreaks.

The authors wish to acknowledge their indebtedness to Drs. Graham, Brueckner, and Pontius, of the Kentucky Agricultural Experiment Station, for the opportunity of using the various sera which they had developed, and also for valuable suggestions. The authors also wish to acknowledge their indebtedness to Mr. H. C. Eckstein, Assistant in Animal Nutrition, and Dr. J. A. Sperry, Associate in Bacteriology, who aided very much in the experimental work.

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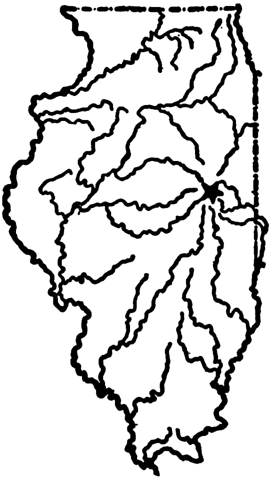
UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

BULLETIN No. 211

APPLE-BUD SELECTION
APPLE SEEDLINGS FROM SELECTED TREES

By CHARLES S. CRANDALL



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APPLE-BUD SELECTION
APPLE SEEDLINGS FROM SELECTED TREES

By CHARLES S. CRANDALL, Chief in Plant Breeding in Horticulture

INTRODUCTION

In addition to hybridizing, which stands as the major project in apple breeding as outlined and undertaken by the Department of Horticulture in 1907, two minor projects in selection were entered upon at the same time. These are:

1. Growing apple trees from selected buds to determine whether or not there are differences in value, for purposes of propagation, between large buds and small buds, between buds produced on different parts of the tree, and between buds from different locations on the shoot.
2. Growing apple seedlings from fruits from trees chosen as possessing special merit.

The nature of the plants is such that the projects must of necessity extend over a considerable number of years. Judgment as to the value of a fruit tree is based upon capacity to bear fruit and upon the character of the fruit produced. It follows that trees propagated from selected seeds or from selected buds must become well established in fruit production before conclusions are possible from which answers to the original questions may be formulated.

It is the purpose of this publication to bring together the records thus far made in connection with these minor projects, to present the methods pursued, and to give the status of the trees growing under each of the projects.

APPLE-BUD SELECTION

This project is an attempt to discover and bring out such differences in value, for purposes of propagation, as are commonly supposed to exist between large buds and small buds, between buds from different situations on the same tree, and between buds from different locations on the same shoot. The trees grown under the project are divided into groups designated as series and numbered by thousands to prevent confusing any of them with numbered groups in other projects.

Selection of the buds began in 1908 and additions were made in each of the three years following. The aggregate is fourteen series represented by 5,400 selected buds distributed as shown in Table 1.

TABLE 1.—DISTRIBUTION OF SELECTED BUDS, BY SERIES

Year	Series	Test	No. of buds	No. of varieties
1908	1 000	Size	100	5
	2 000	Location on tree	450	5
	3 000	Location on shoot	320	5
1909	4 000	Location on tree	750	13
	5 000	Location on shoot	430	10
	6 000	Size	220	11
	7 000	Location on tree	290	6
	8 000	Location on shoot	190	6
1910	9 000	Location on tree	840	12
	10 000	Location on shoot	450	11
	11 000	Size	240	12
1911	12 000	Location on tree	530	11
	13 000	Location on shoot	330	11
	14 000	Size	260	13
		Total	5 400	

When one year old, all living trees in the 4,000, 5,000, and 6,000 series, originally represented by 1,400 selected buds, were transferred to the Station farm at Olney and, because of incomplete growth records, are not to be further considered at this time. The two other series selected in 1909, the 7,000 and 8,000 series, differ from all other series in that here, the selected buds, instead of being propagated by grafting in the spring, were budded in August of that year, and as they were dormant until the next spring, the trees rate, as to age, with those selected and propagated in the spring of 1910.

Of the eleven series here considered, three, with 600 selected buds, represent the comparison between large and small buds; four series, with 2,110 buds, represent the test of location on tree; and four, with 1,290 buds, represent the test of location on shoot.

Numbers of buds in the different series varied for two reasons; in some cases the time available for making grafts was limited; in other cases series were incomplete because buds desired were not available. These irregularities occurred mainly in those series including buds from different locations on the tree.

Buds from twenty-one varieties were used, but these varieties did not have equal representation. Five varieties were represented in nearly all series; these were Yellow Transparent, Oldenburg, Winesap, Grimes, and Ben Davis. Other varieties represented in one or more of the series were Jonathan, Fameuse, Minkler, Kinnard, Willow, Whitney, Rome, Osimoe, Huntsman, Isham, Twenty Ounce, Dominie, Arkansas Black, York Imperial, Cornell, and Sweet Bellflower.

TEST OF SIZE: LARGE BUDS AND SMALL BUDS

The test of size of buds included three series: the 1,000 series of 100 buds, selected in 1908; the 11,000 series of 240 buds, selected in 1910; and the 14,000 series of 260 buds, selected in 1911.

THE 1,000 SERIES

Buds were selected in groups of ten and, using scions approximately six inches in length, were root-grafted, by the veneer method, on ordinary apple stocks. For the 1,000 series, the numbers 1,001 to 1,010 were given to the grafts made with the ten selected buds of large size, and the numbers 1,011 to 1,020 to the grafts made with the selected buds of small size, all from the same Yellow Transparent tree. This plan of numbering was also used for the varieties Oldenburg, Ben Davis, Winesap, and Grimes. There were then 100 grafts in this series as made up in February, 1908.

In selecting for large size, terminal buds from central terminal shoots on bearing trees were chosen, because these, in most varieties, were the largest to be found on the trees. With Grimes, however, the terminal buds of terminal shoots were quite small, many of them protruding but little from the concavity formed by the enlargement of the tip of the shoot. Short lateral shoots just below the terminal shoots were, in most cases, crowned with large, well-developed terminal buds, and these were the buds selected in this variety. It occasionally happened in other varieties that on vigorous terminal shoots the apical bud was undeveloped, the food supply having been appropriated by an adjacent bud in an upper axil. In such cases the large lateral bud was the one selected. The small buds were, in most cases, lateral buds from short interior branches, but with Grimes, terminal buds of interior branches were selected as being smaller than the laterals on these branches, or on other branches elsewhere on the tree. When a lateral bud was selected, the shoot was cut back to this bud so that in all grafts the chosen bud was at the distal end of the scion. The scions were tied with raffia, the unions waxed with alcoholic plastic, and the grafts stored in moist sphagnum until the series was complete; they were then transferred to sand, where they remained until planted in the field, May 12, 1908. Table 2 shows the averages for length and diameter of shoot, and the number of buds; and, for buds, the averages for length and diameter, and also the length of scion and the number of buds on scion used.

At the time of planting the grafts (May 12), the selected buds appeared to be in good condition, but when checked over twenty-four

TABLE 2.—TEST OF SIZE OF BUDS: MEASUREMENTS OF SELECTIONS OF 1908

Variety	Size of buds	Serial numbers	Shoot					Bud		Scion	
			Average length (cm.)	Average diameter (mm.)			Average No. of buds	Average length (mm.)	Average width (mm.)	Average length (cm.)	Average No. of buds
				Basal	Middle	Distal					
Yellow Transparent...	Largest	1001-1010	36.0	6.7	4.0	3.6	18	6.4	4.6	16.5	9
	Smallest	1011-1020	17.5	5.0	2.7	2.5	12	4.8	3.2	15.0	11
Oldenburg...........	Largest	1021-1030	12.0	6.3	4.1	4.6	17	5.5	4.4	13.5	10
	Smallest	1031-1040	26.0	5.2	3.5	3.4	18	1.8	1.9	14.8	9
Grimes..............	Largest	1041-1050	16.0	4.4	3.0	2.8	10	6.7	4.4	15.6	9
	Smallest	1051-1060	14.8	3.8	2.5	2.1	9	3.9	3.2	14.8	9
Winesap.............	Largest	1061-1070	23.2	6.6	4.5	4.5	28	6.4	4.6	16.2	15
	Smallest	1071-1080	23.0	3.9	2.5	2.5	19	4.6	3.3	16.2	13
Ben Davis	Largest	1081-1090	29.8	6.0	4.0	4.7	20	6.2	4.7	16.8	13
	Smallest	1091-1100	30.8	5.5	3.5	3.5	21	2.8	2.4	15.7	10

days later it was found that eleven of the buds had not started or had started and immediately died. These failures were fairly well distributed. Six were in lots of large buds and five in lots of small buds. The buds that were growing on June 6 exhibited all degrees of vigor. Some were strong, others so weak that their early death was foreseen. When the plants were taken up for winter storage (November 3), 77 were living; most of them were fairly vigorous, but a few were small and weak. Of the 23 failures, 12 were of small buds and 11 of large buds. The greatest loss in any one lot was five of the small buds of Winesap, and next to this was the loss of four of the large buds of Ben Davis. One lot, the small buds of Oldenburg, came thru this first season with the full complement of ten. During 1909 six of the weak trees died, so that at the close of this second season the losses totaled 29. In the spring of 1910 the remaining 71 trees of this series were planted in orchard. Four more trees died during this third season. More serious losses occurred during the first winter in orchard. Of the 17 trees recorded as dead in the fall of 1911, some had not started in the spring and some had made a feeble effort at growth and then died. Thus 50 percent of the buds included in this series dropped out during the first three years. The 50 trees remaining are established, and altho exhibiting differences in vigor, should reach maturity unless lost thru accident.

Of the trees lost, a few were destroyed by rabbits or were broken down by storms, but the chief cause of loss appeared to have been weakness or want of vitality, whether in the buds chosen, in the scion, or in the stock, it was not possible to determine. In considering distribution of the losses, there is nothing to suggest a superior vitality on the part of large buds; in fact, the number of failures of large buds was two greater than the number from small buds. For three varieties the losses were equally divided between large and small buds, for one variety the loss for small buds was greater, and for another the loss for large buds was greater. Trees living in 1915 were divided as follows: Yellow Transparent, one from large bud and one from small; Grimes and Ben Davis, six each from large and small; Winesap, six large and four small; Oldenburg, five large and nine small.

Growth of Trees in Relation to Size of Buds from which Propagated

The basis of comparison of trees is vigor as indicated by growth increment. For the first two years the leader and branches were measured and the total was recorded for each tree, but as the trees increased in size this procedure became impracticable. In the third year (1910) growth of leader only was recorded, and in succeeding years measurements of height and spread only were recorded. This change destroys the uniformity of the record, but does not in any way interfere with the comparison it is desired to make between the two groups of trees, those from large buds and those from small, in the matter of growth.

At no time during the eight years of this experiment did there appear any striking differences between the groups of trees from large buds and those from small buds. There were and still are marked differences between individuals in the same group, but the summation of growth records for the different groups shows that they closely approximated thruout. Bringing the averages of growth together, in tabular form, by years, and for the last five years considering total height only, they are as shown in Table 3.

TABLE 3.—COMPARISON OF GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: 1,000 SERIES

Variety	Size of bud	No. of trees	Average of growth (inches)							
			1908	1909	1910	1911	1912	1913	1914	1915
Yellow Transparent...	Large	1	21	11	11	37	40	53	74	92
	Small	1	17	6	9	42	50	60	72	93
Oldenburg	Large	5	15	26	11	46	49	63	70	92
	Small	9	11	20	12	37	45	58	72	93
Grimes.........	Large	6	19	20	9	42	51	64	80	102
	Small	6	21	16	8	38	47	53	64	90
Winesap	Large	6	28	17	9	46	55	70	88	116
	Small	4	21	10	11	46	56	72	89	113
Ben Davis	Large	6	28	19	9	43	52	64	78	98
	Small	6	20	21	7	46	56	69	84	109

NOTE.—Total growth is given for 1908 and 1909, for 1910 growth of leader only, and for each succeeding year total height of tree.

There is nothing in these figures, nor was there anything to be derived from inspection of the trees in orchard, to suggest the existence of any marked difference between large buds and small buds in their value for purposes of propagation. The approximation of the growth curves of the classes here under consideration is, perhaps, more clearly indicated in the accompanying graphs platted from the measurements given (Figs. 1 to 6). The number of plants is small and therefore the basis for conclusions is less reliable than if the number were greater. However, careful study of the trees from year to year strengthens the belief that an increase in the number of trees would tend towards nearer coincidence of the lines rather than towards their greater separation.

With Yellow Transparent, only one tree of which remained in each of the two groups, the tree from large bud was in advance of the tree from small bud in the three early years. In the fourth year it fell behind the tree from small bud and remained in this position for the two following years. In the seventh year it again took the lead by a narrow margin, but the last year it again fell slightly behind. Oldenburg, of which there were five trees from large buds and nine from small buds, except for a slight advantage on the part of trees from small buds in the third year, showed a greater average growth of the trees from large buds than of those from small buds thru the sixth year. In the seventh year trees from small buds gained a slight advantage over those from large buds and this was maintained thru the eighth year. Grimes, with six trees in each group, showed a slightly better average growth by trees from large buds than by trees from small buds. With Winesap, having six trees from large buds and four from small buds, the trees from small buds had a slight advantage from the third to the seventh year and in the eighth year dropped slightly below the trees from large buds, but the lines thruout are so nearly parallel that neither group can be regarded as superior to the other. Ben Davis trees, with six in each group, showed a slight advantage on the part of those from small buds.

Combining the varieties and platting the average growth of the 24 trees from large buds with that of the 26 from small buds, there appears such close coincidence in the lines as to indicate no appreciable difference in value between large buds and small buds for purposes of propagation. A large bud may make a stronger initial growth than a small one, but the supply of nutrients in either bud will be quickly exhausted; then, which takes precedence in growth will depend, not upon the original size of the bud, but upon which has the larger store of reserve food materials in adjacent parts, or which is the better supplied from the stock upon which it is grafted, subject, of course, to other factors which may influence the availability of the reserve food supply.

Individual trees from large buds and from small buds for each of the three varieties Ben Davis, Grimes, and Winesap are shown in Figs. 7 to 12, which are from photographs made in July, 1915. Close proximity of trees in some cases restricted positions and interfered with absolutely uniform camera distance. This resulted in some slight inaccuracies in relative size, and for this reason height of tree as measured October 13, 1915, accompanies each plate.

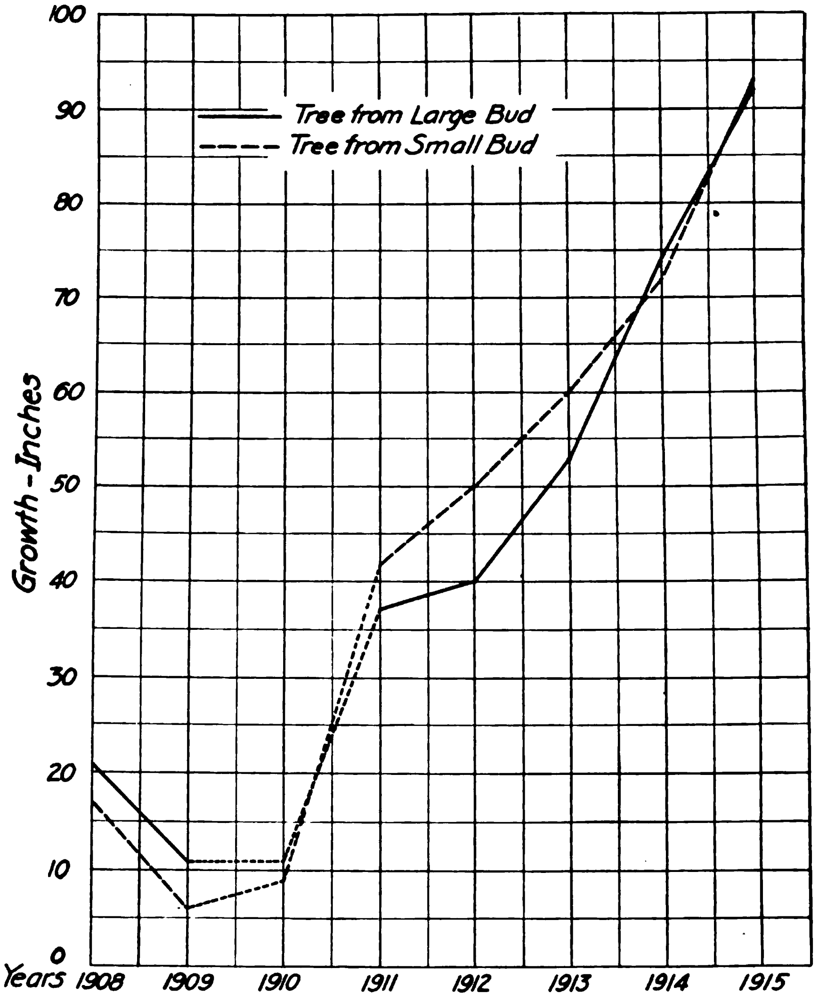

FIG. 1.—SHOWING THE GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: YELLOW TRANSPARENT, 1,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

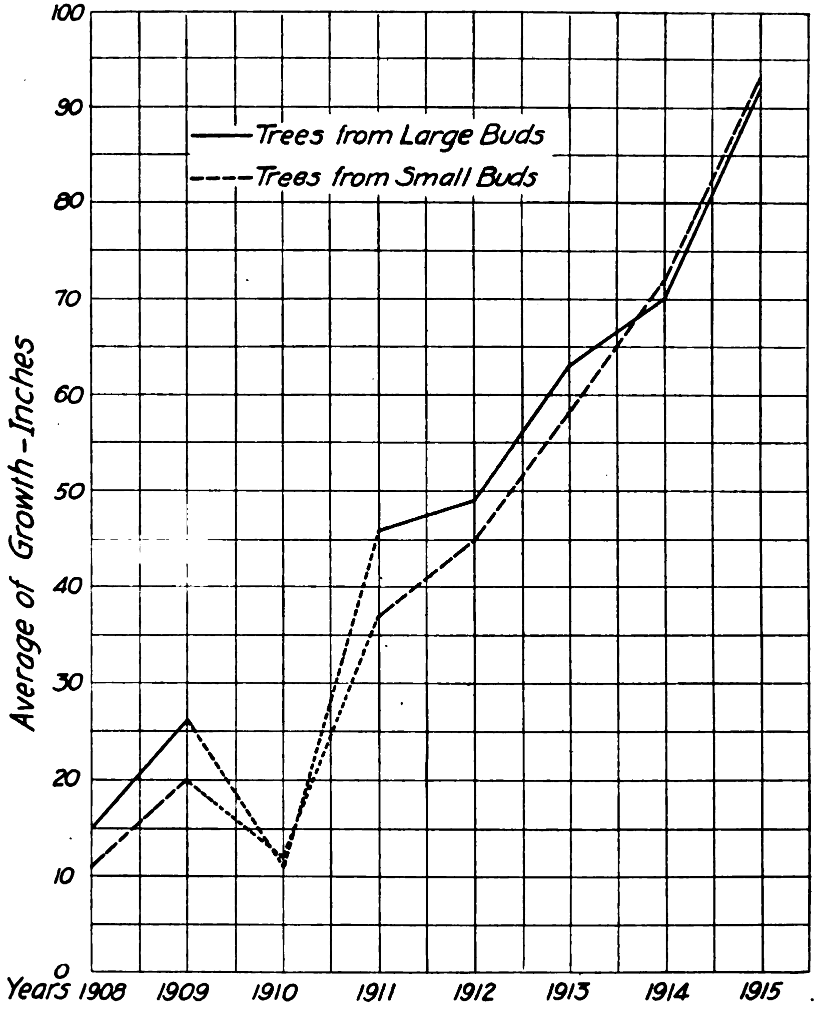

FIG. 2.—SHOWING THE GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: OLDENBURG, 1,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

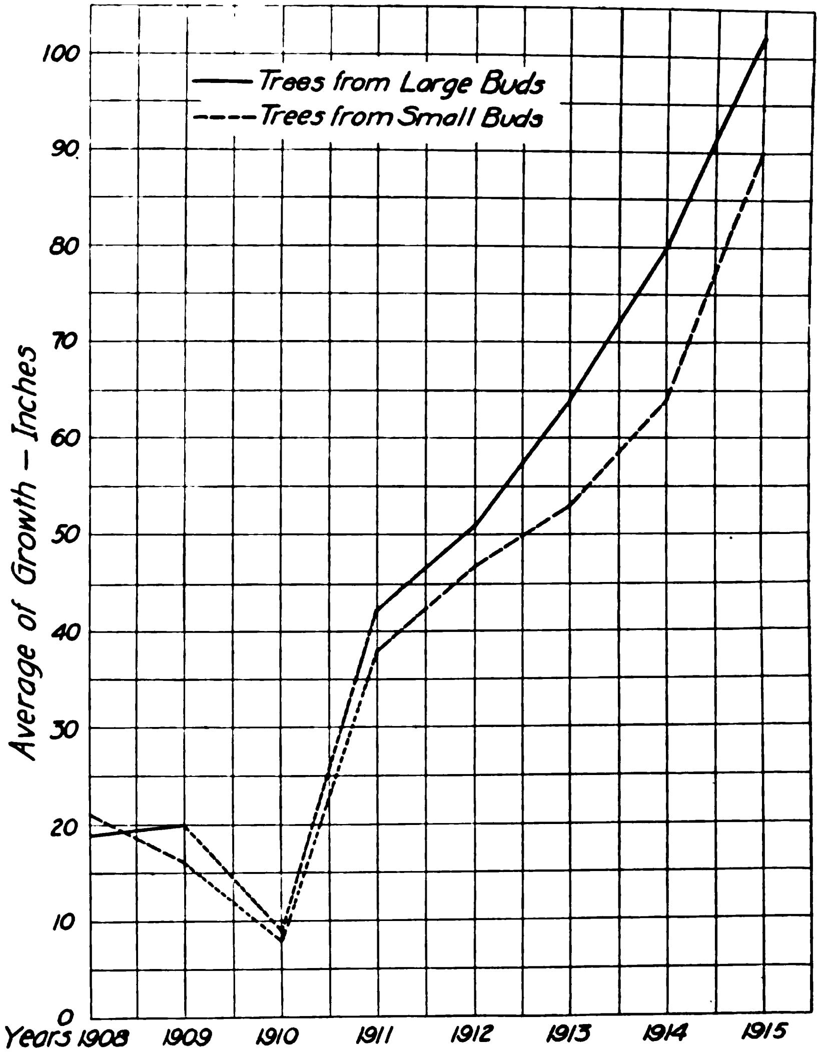

FIG. 3.—SHOWING THE GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: GRIMES, 1,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

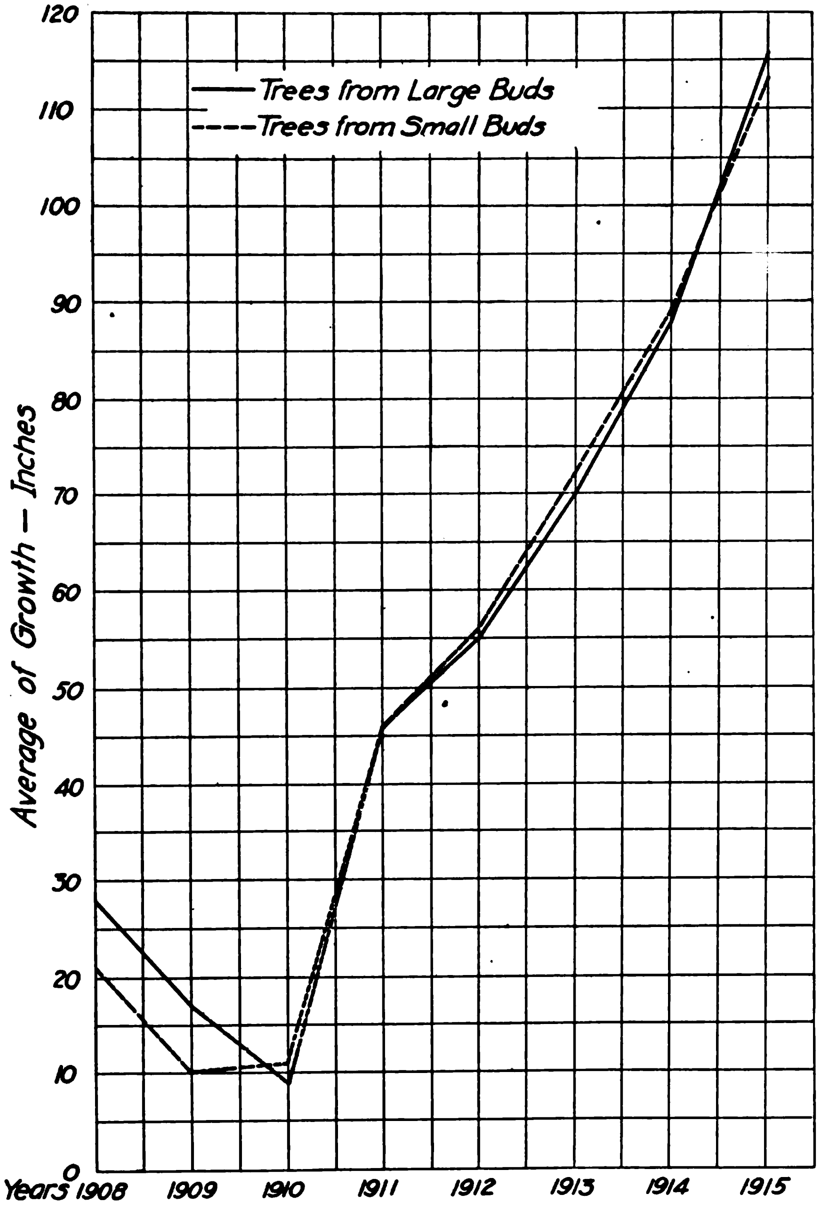

FIG. 4.—SHOWING THE GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: WINESAP, 1,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

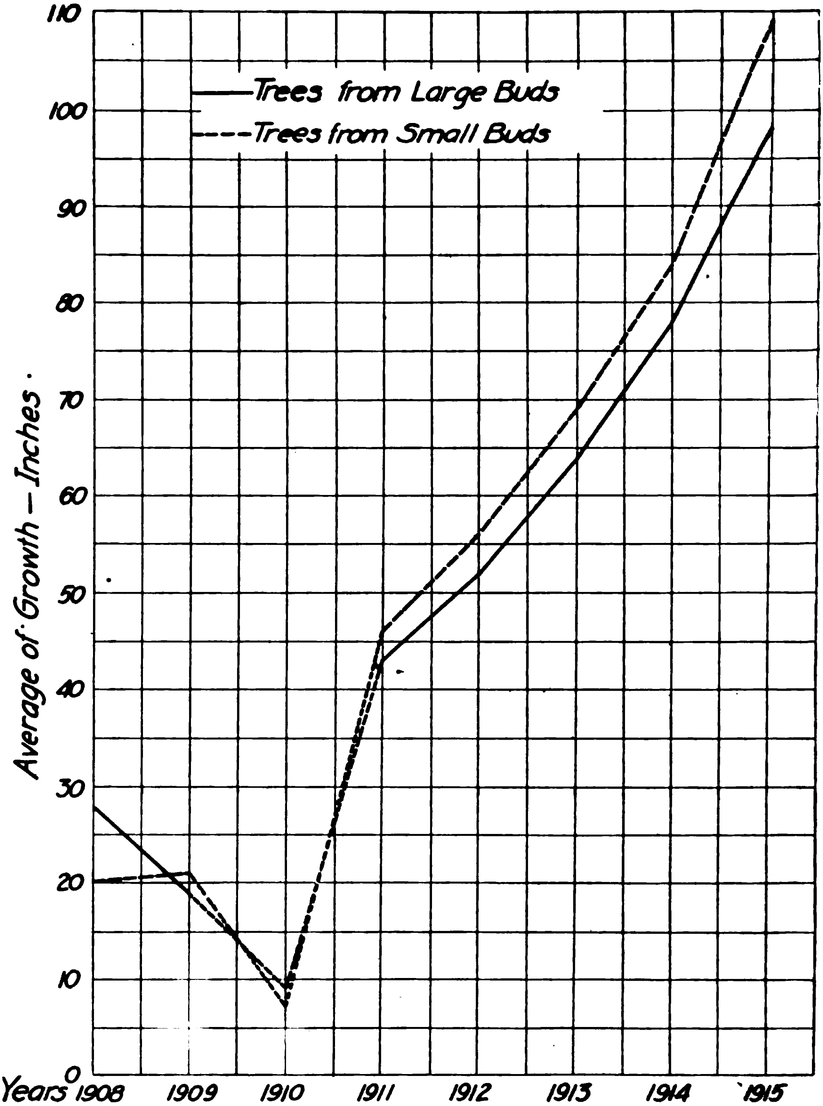

FIG. 5.—SHOWING THE GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: BEN DAVIS, 1,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

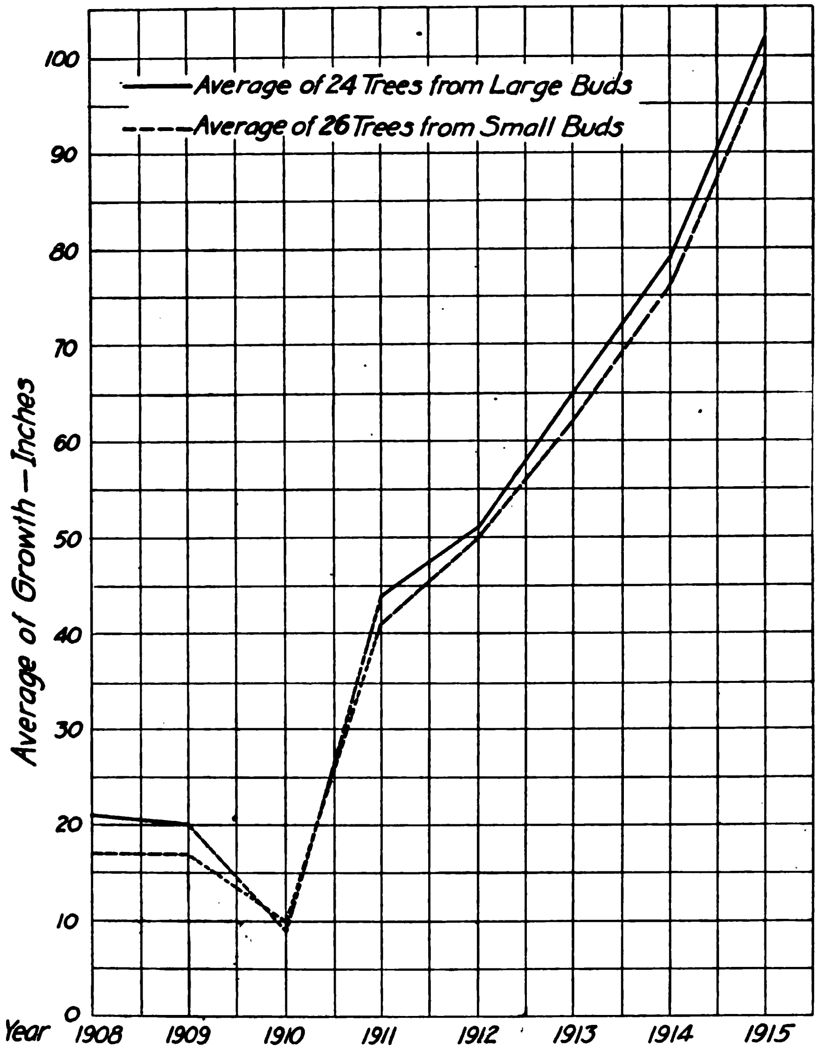

FIG. 6.—SHOWING THE GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: THE FIVE VARIETIES COMBINED, 1,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

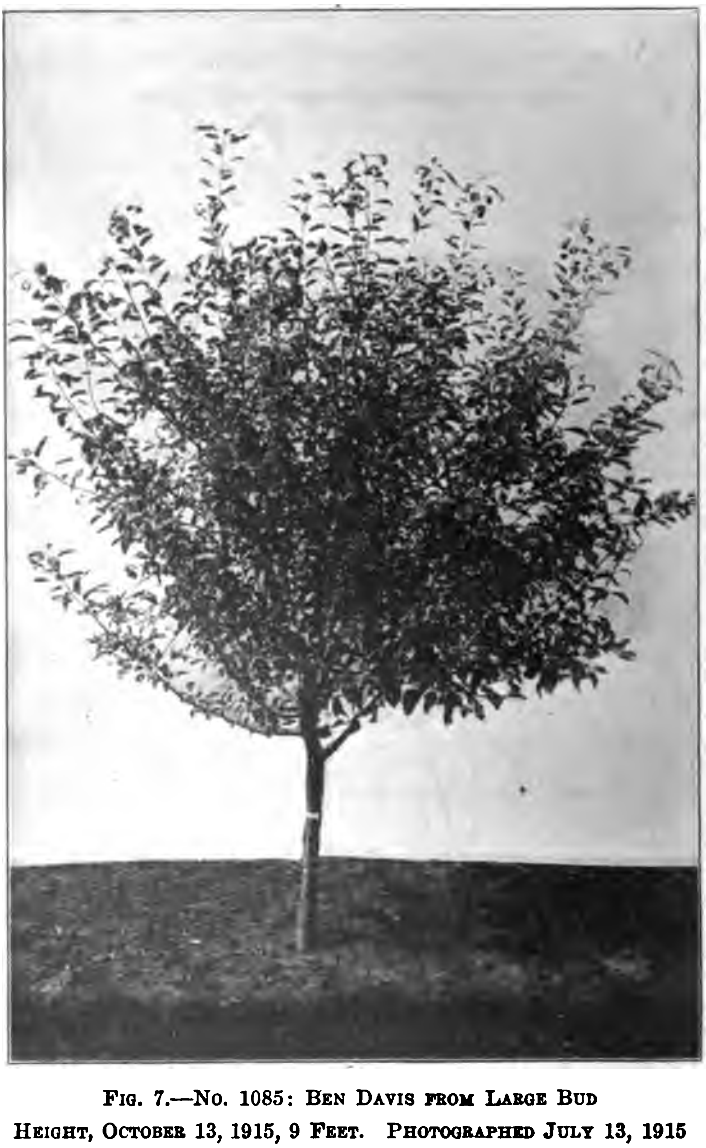

FIG. 7.—NO. 1085: BEN DAVIS FROM LARGE BUD
HEIGHT, OCTOBER 13, 1915, 9 FEET. PHOTOGRAPHED JULY 13, 1915

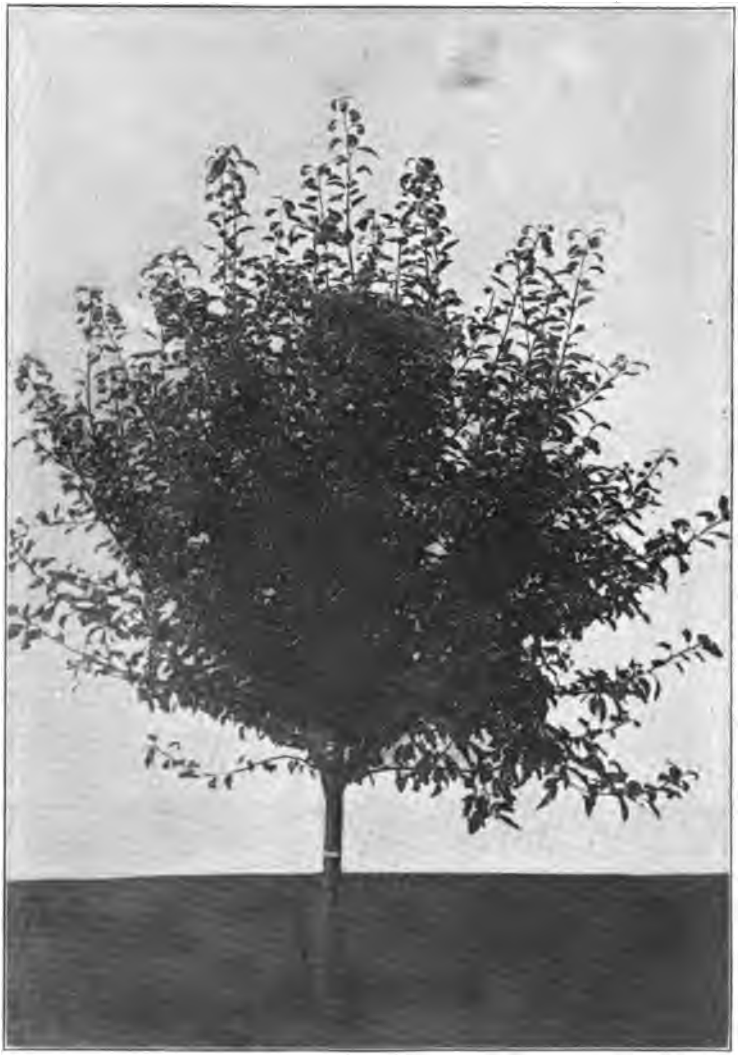

FIG. 8.—NO. 1093: BEN DAVIS FROM SMALL BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET. PHOTOGRAPHED JULY 13, 1915

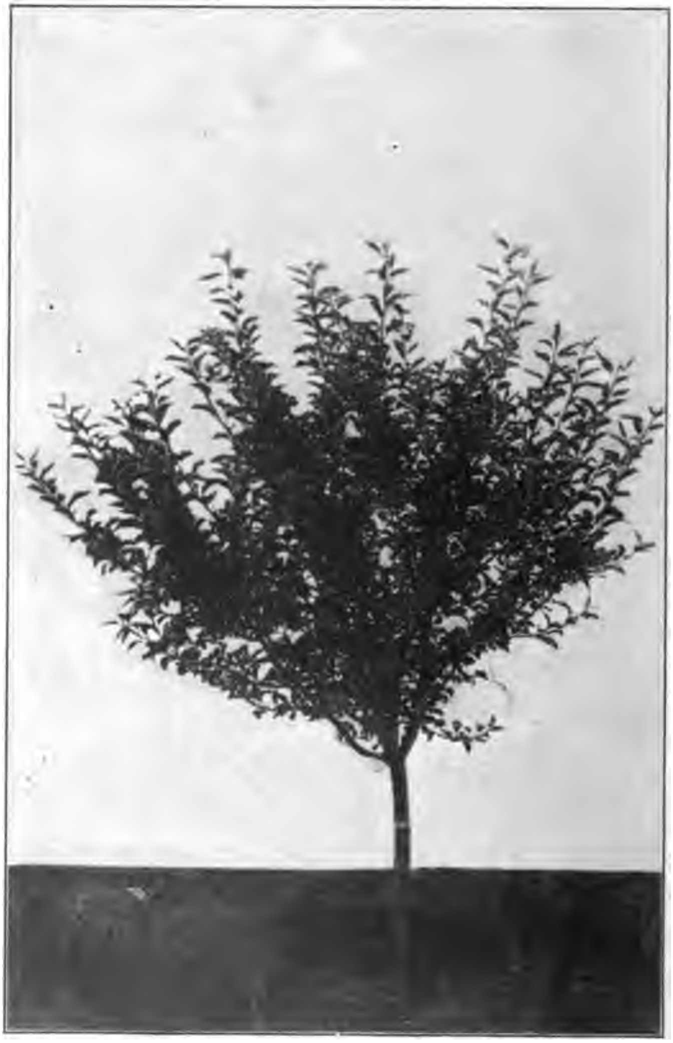

FIG. 9.—NO. 1047: GRIMES FROM LARGE BUD
HEIGHT, OCTOBER 13, 1915, 8 FEET, 1 INCH. PHOTOGRAPHED JULY 14, 1915

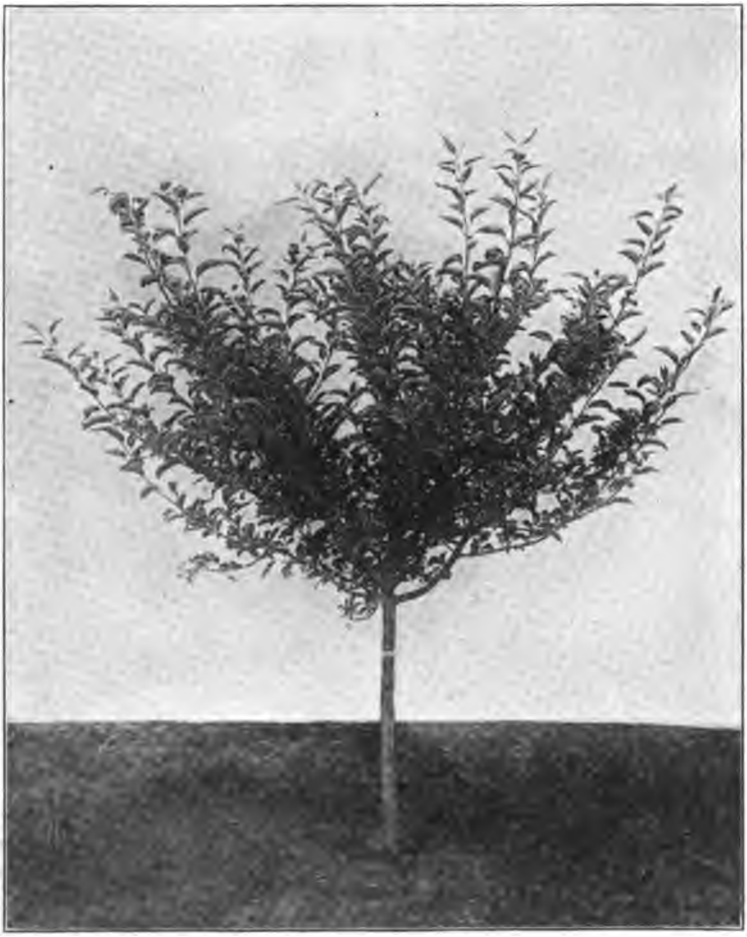

FIG. 10.—NO. 1051: GRIMES FROM SMALL BUD
HEIGHT, OCTOBER 13, 1915, 7 FEET, 2 INCHES. PHOTOGRAPHED JULY 14, 1915

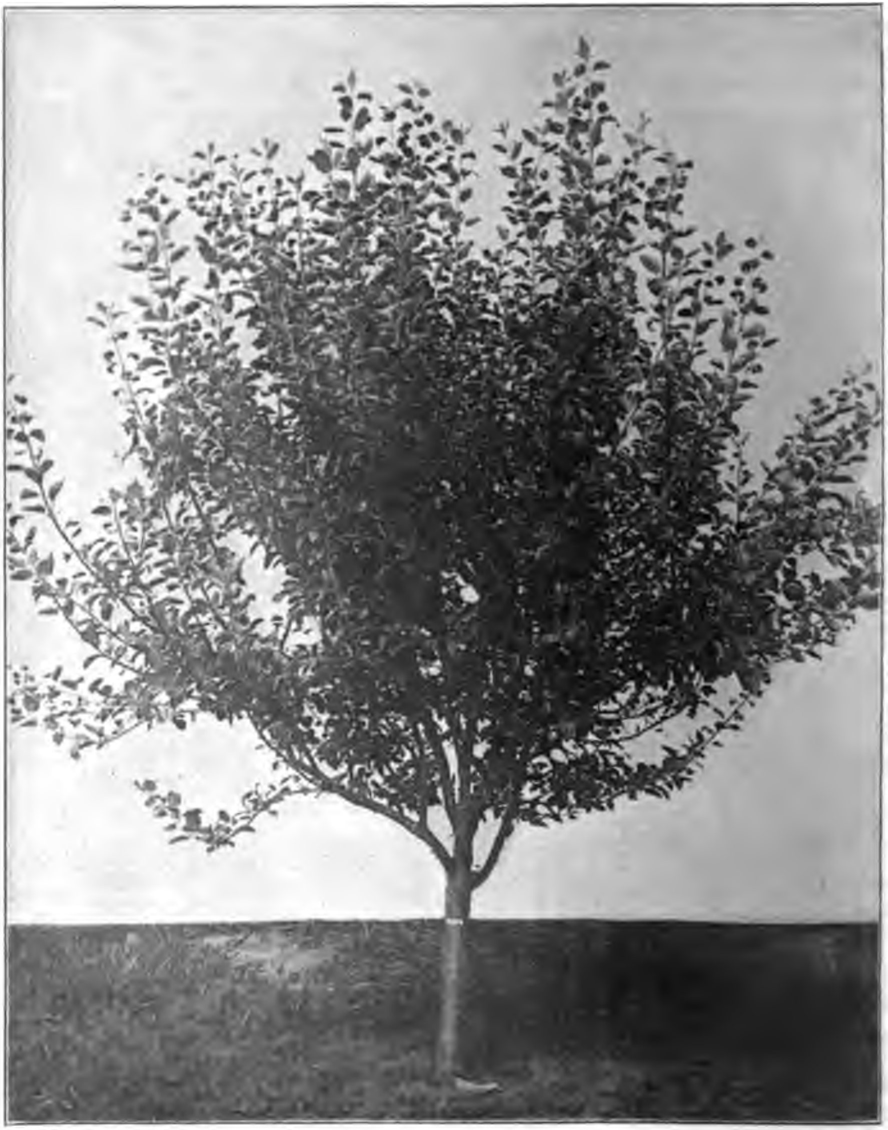

FIG. 11.—NO. 1068: WINESAP FROM LARGE BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET, 6 INCHES. PHOTOGRAPHED JULY 14, 1915

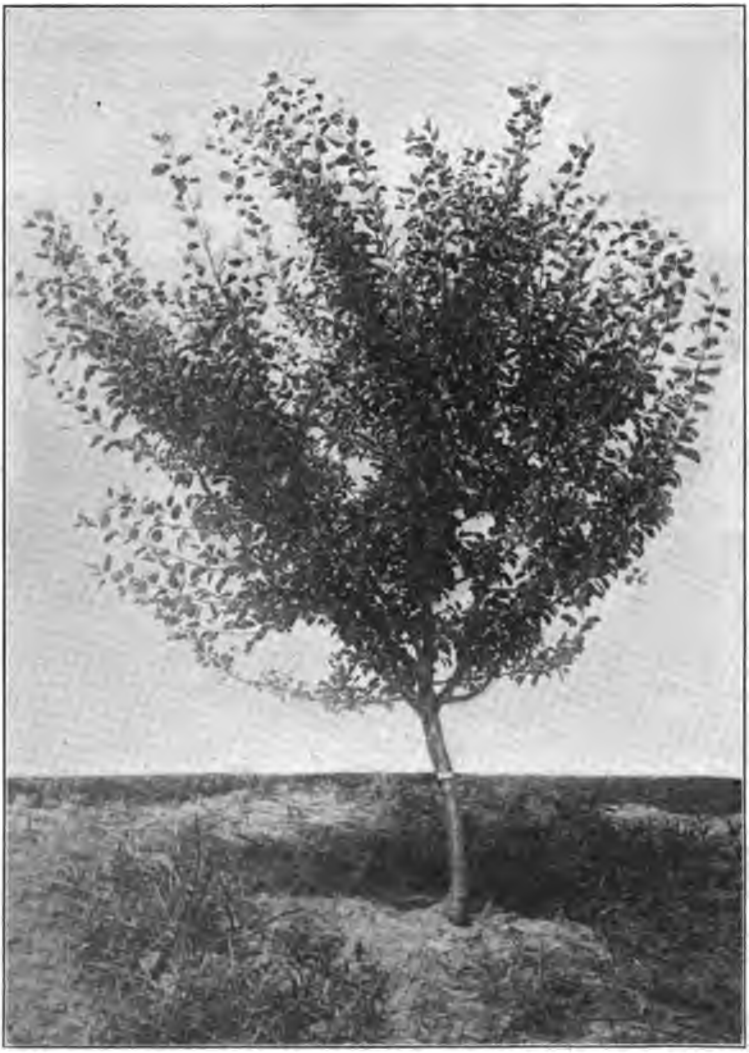

FIG. 12.—No. 1073: WINESAP FROM SMALL BUD
HEIGHT, OCTOBER 13, 1915, 9 FEET, 11 INCHES. PHOTOGRAPHED JULY 14, 1915

Other Factors Affecting Growth of Trees

In general it would seem that plumpness and healthy appearance of the scion shoot should offer a better basis upon which to judge value for purposes of propagation than does size of buds.

In each of the years 1912, 1913, 1914, and 1915, an inspection of the trees in this series was made, from which judgment was recorded as to grade, rating them as "good," "fair," and "poor." The results are shown in Table 4.

TABLE 4.—GRADES OF TREES FROM LARGE BUDS AND FROM SMALL BUDS: 1,000 SERIES

	Number of trees											
	1912			1913			1914			1915		
	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor
Large buds..	7	12	5	10	12	2	20	2	2	22	1	1
Small buds..	8	12	6	11	12	3	15	9	2	23	2	1

These figures exhibit a rather striking improvement in quality with each succeeding year. Trees from large buds rated as good jumped from 29 percent in 1912 to nearly 92 percent in 1915, and trees from small buds rated as good changed from 31 percent in 1912 to 88 percent in 1915. While five trees from large buds and six from small buds were rated as poor in 1912, only one from large bud and one from small bud were so rated in 1915. Further changes in the same direction are expected in succeeding years.

This expectation is based upon the aggregate of experiences, of the past ten years, in growing apple root-grafts and apple seedlings on the black soil of this locality. The top soil does not appear to be adapted to the promotion of growth in young apple trees. Whether this is because of texture, deficiency in some essential food element, the presence of some deleterious ingredient, or the presence or absence of some soil organism, is not known. The difficulty may be physical, chemical, or biological, surely one or all of these factors, because it is habitually the case that newly planted root-grafts or transplanted seedlings make very unsatisfactory growth during the first, second, third, and sometimes fourth years. After the third or fourth year there is usually a very marked increase in the annual growth increment, which continues to augment until fruiting maturity is reached. It appears that a certain period is necessary for roots to penetrate to and become established in the subsoil, and that the subsoil supplies conditions more favorable to growth than those encountered in the top soil. This is only suggested as one possible cause for the behavior observed. The subject is one that offers attractions as a field for investigation.

THE 11,000 SERIES

The 11,000 series, selected in 1910, consisted of 240 buds representing twelve varieties. With ten of the varieties all the losses occurred in the first year; with two varieties the losses occurred in the second year. No losses occurred after the second year in this series. With Rome the loss was total in the second year, altho at the close of the first year nine trees were living in each group. Isham was reduced to one tree in each group at the end of the second year. Only one tree each of Ben Davis and Twenty Ounce survived the first year, the Ben Davis a tree from large bud, the Twenty Ounce a tree from small bud. Living trees of other varieties ranged from three to nine in each group. At the end of the sixth year there were living 57 trees from large buds and 41 trees from small buds. Growth increments of trees from large buds compared with those of trees from small buds were almost identical. Trees from large buds had a slight advantage in the first year, the increment was equal in three years, and differed by only one inch in the other two. The uniformity in growth of trees in the two groups was even more marked here than in the 1,000 series.

THE 14,000 SERIES

The 14,000 series, selected in 1911, included 260 buds representing thirteen varieties. The losses in this series aggregated greater than in either of the other series in the test of size, and, instead of being confined to the first two years as in the 11,000 series, were distributed thru the five seasons. There were living in 1915, 39 trees from large buds, or 30 percent of the original selections, and 34 trees from small buds, or 20 percent. The small-bud groups of Fameuse and Willow were lost entirely, and those of Oldenburg and Isham were reduced to one tree each. The large-bud groups of Twenty Ounce and Huntsman were also reduced to one tree each. The curve of average growth for all varieties shows that the two groups made equal growth in the first year, that for the second year the small-bud group gained a slight advantage, then dropped slightly below in the third year and remained below in the two following years, altho exhibiting a tendency to greater growth that promised to bring the two groups to equality in another year.

DISCUSSION OF RESULTS

In the three series of trees here considered in detail there were, in 1915, 221 trees living in orchard. Of these, 120 were grown from large buds and 101 from small buds. Divided according to age, 24 from large buds and 26 from small buds were eight years old, 57 from large buds and 41 from small buds were six years old, and 39 from large buds and 34 from small buds were five years old.

In the fall of 1915 the trees were carefully inspected and classified as follows:

	Large buds	Small buds
Good	77	65
Fair	31	25
Poor	12	11

The percentages are very nearly the same for the two groups—approximately 65 percent good, 25 percent fair, and 10 percent poor. Here, as in every other comparison attempted between trees from large buds and those from small buds, there were no tangible differences by which the two groups could be separated.

Individual growth differences between trees within groups, as has already been mentioned, were in some cases extreme. Thus, nine Oldenburg trees of the 1,000 series grown from small buds, had, at the close of the eighth year, a height range from 36 inches to 127 inches—the tallest more than three and one-half times the height of the shortest. The companion group of five trees of Oldenburg from large buds had an individual range from 62 inches to 104 inches; in this group the shortest would have to be increased by nearly 68 percent to make it equal the tallest. Other similar groups of the same series showed differences requiring additions to the shortest of from 21 to 55 percent to make them equal the tallest.

The comparisons that have been given between trees propagated from large buds and those propagated from small buds, together with the aggregate of impressions derived from careful inspections of trees of all groups, leave no question regarding conclusions. The only possible conclusion from the summarized data is that there are no differences in value, for purposes of propagation, between buds of large size and those of small size.

COMPARATIVE VALUE OF BUDS FROM DIFFERENT LOCATIONS ON TREE

Investigations were made in an attempt to determine whether or not there are differences in value, for purposes of propagation, between buds taken from different parts of the tree. Five classes of buds, all from mature trees, were determined upon as representative of possible differences that might arise from exposure or situation. These were as follows:

1. Terminal buds from central terminal shoots
2. Terminal buds from extreme lateral shoots on south side of tree in full exposure to sun
3. Terminal buds from extreme lateral shoots on north side of tree and for the most part shaded
4. Terminal buds from short interior branches
5. Terminal buds or scions from centrally located water sprouts

The same procedure as that adopted for the test of size was used; that is, ten buds were chosen to represent each of the five groups for each variety, and as many varieties were used as time for the work allowed. Scions were grafted on ordinary apple-seedling stocks and the grafts were handled according to common practice with root-grafts. The one departure from this practice was in one series of 1909, where the buds, instead of being selected and grafted in late winter, were chosen and budded on seedling stocks in August.

For the sake of uniformity, the attempt was made to include only terminal buds, and this was with few exceptions carried out for three of the variety groups, but in the two remaining variety groups difficulty was encountered, especially in regard to buds from water sprouts. With some varieties water sprouts were absent, and when they were present it was frequently the case that terminal buds had not been formed, or, if formed, they had gone into the winter in such an immature condition that they were destroyed by even moderate freezing. Where water-sprout tips had been injured, the uninjured lateral buds nearest the extremity of the shoots were chosen. Where short interior branches were present, there was usually no difficulty in obtaining terminal buds, but some varieties did not possess branches such as were desired for this group and in these cases the group was of necessity omitted.

The work of selecting and measuring buds was begun in the spring of 1908, and additions were made in each of the three seasons following. Locating the position and recording the dimensions of the buds established individuality for each, and for purposes of identification at any time thruout the life of the prospective tree, some designation was necessary that should be inseparable from the individual until the tree was permanently planted and its position accurately platted in permanent record. This identity of individuals was secured by a system of numbering. The buds selected in any one season constituted what has been called a "series." Thus the "2,000 series" was composed of 450 buds from five varieties selected and root-grafted in 1908; the "7,000 series" included 290 buds from six varieties selected and budded in August, 1909; the "9,000 series," 840 buds from twelve varieties selected and grafted in 1910; and the "12,000 series," 530 buds from eleven varieties selected and grafted in 1911. In each series the individual numbers were from one up. Thus the ten terminal buds on top central shoots of Ben Davis bore the numbers 2,001 to 2,010, the ten terminal buds from lateral shoots south, the numbers 2,011 to 2,020, and so on thru the series. On painted wooden labels about two inches long and one-quarter inch wide, notched at both ends, the numbers were painted with shellac and lampblack, and a label with number corresponding to the number in the descriptive record of the bud was attached, when the graft was made, by a copper wire band at each end. After the grafts were planted in nursery in strictly numerical order it was necessary to remove the labels, but this was not done until stake labels for each group of ten were in place and the whole planting had been carefully checked with a previously prepared record. In the fall, if the plants were to be lifted for winter storage, the labels were again adjusted.

This matter of individual labels for several hundred small plants may appear as a simple detail, but in reality it was the most important, and, at the same time, the most exacting procedure in connection with the test undertaken. If the identity of a plant is lost, the plant is of no value and must be discarded; not only is the labor expended upon it lost, but the value of the ultimate results of the experiment are more or less imperiled, because in any such experiment, numbers have weight and any decrease in numbers diminishes by a definite amount the value of final results. Therefore effort expended in devising and applying means of insuring permanent identity for individuals is imperative.

LOSSES IN THE VARIOUS SERIES

In this test of buds from different locations on the trees the aggregate of buds selected, measured, and propagated was 2,110, divided unequally among fifteen varieties. Nearly 70 percent of the buds were from the five varieties Ben Davis, Winesap, Oldenburg, Yellow Transparent, and Grimes, for the reason that these varieties, being most readily available, were represented in all the series, while the others appeared in only one or two of the later series and were, in large part, from selected trees in orchards in the southern part of the state. The varieties thus represented by smaller numbers were Jonathan, Arkansas Black, Kinnard, Minkler, Huntsman, Whitney, Fameuse, Rome, Willow, and Isham.

Altho careful attention was given to all details of propagation and storage thru the interval between grafting and planting in nursery, the losses during the first season were heavy with all series, particularly with the 7,000 series, which was budded in August, 1909. In this series the loss resulted chiefly from failure of the buds to take, and this failure is ascribed to extreme drouth during and following the budding season. In the grafted series a considerable share of the loss occurred by reason of failure of chosen buds to vegetate, but this source of loss was not so pronounced as in the budded series. With all series losses occurred thru the breaking of young shoots by storms, and thru depredations by cutworms, mice, and rabbits. The number of living plants in the various series, after growing one year in nursery, is shown in Table 5.

Losses continued to occur in succeeding seasons, due in part to winter injury, in part to the death of weak individuals that had made but feeble growth from the beginning, and in part to accidents resulting from wind. The total number of living trees in 1915 was 734, representing approximately 35 percent of the 2,110 buds selected. They were distributed as shown in Table 5.

TABLE 5.—LOCATION OF BUD ON TREE: ENDURANCE OF TREES, BY SERIES

Series	Number of buds selected	Trees living after one year in nursery			Trees living at close of eighth year		
		Year	Number	Percentage of total	Age (years)	Number	Percentage of total
2 000	450	1908	278	61.77	8	129	28.66
7 000	290	1909	64	22.06	6	23	7.93
9 000	840	1910	561	66.78	6	436	51.90
12 000	530	1911	226	42.64	5	146	27.54

ENDURANCE OF TREES BY VARIETAL GROUPS

Classification of the trees according to varieties is not wholly satisfactory because of differences in age and in numbers of buds selected, but for purposes of record the status of the varieties as to number of trees living in November, 1915, together with the percentage of the original selections, is given in Table 6; the varieties are arranged in sequence from the higher to the lower percentages.

TABLE 6.—LOCATION OF BUD ON TREE: ENDURANCE OF TREES, BY VARIETIES

Variety	No. of buds selected	Trees living after eight years	
		Number	Percentage of total
Minkler	50	36	72.00
Arkansas Black	30	20	66.66
Whitney	80	46	57.50
Willow	50	25	50.00
Fameuse	100	46	46.00
Grimes	310	141	45.48
Huntsman	90	36	40.00
Oldenburg	260	84	32.30
Kinnard	50	16	32.00
Isham	50	16	32.00
Winesap	290	90	31.03
Ben Davis	320	97	30.31
Rome	50	12	24.00
Jonathan	140	30	21.42
Yellow Transparent	240	48	20.00

The higher percentages here fall to varieties having few buds and representation in but one or, at most, two of the series in which the trees were in part six years old and in part five years old. The five varieties Grimes, Oldenburg, Winesap, Ben Davis, and Yellow Transparent were all represented in each of the four series and together represented over 67 percent of the buds selected and about 62 percent of living trees. They give a basis for judging endurance that is perhaps better than that given by the complete list of varieties. Percentages of trees of these varieties living in the fall of 1915, or after eight years, ranged from 45.48 percent for Grimes to 20 percent for Yellow Transparent. Other percentages are 32.3 for Oldenburg, 31.03 for Winesap, and 30.31 for Ben Davis. The average for the five varieties is 31.82 percent.

Eliminating the 7,000 series, in which budding was substituted for grafting and wherein failure of buds to start resulted in very few trees, and considering the three grafted series only, it may be noted that there were differences in these series that were in the nature of seasonal differences. Thus, for the 2,000 series, of 1908, Oldenburg led with 35 percent of the buds selected persisting as trees in the fall of 1915. Ben Davis and Grimes were equal and followed a little below Oldenburg, Winesap followed next, and last Yellow Transparent with only 15.5 percent of the buds represented as living trees. For the 9,000 series, of 1910, Grimes was far in the lead in number of living trees, nearly 70 percent of the selected buds being represented by trees; this was followed by Oldenburg, Yellow Transparent, Winesap, and Ben Davis in the order named. In the 12,000 series, of 1911, Grimes was again in the lead, but with a much lower percentage than that shown in the 9,000 series. This was followed by Winesap and Yellow Transparent in descending order and then by equal values for Ben Davis and Oldenburg. In general, Grimes proved the most satisfactory; the other four varieties followed in this order: Oldenburg, Winesap, Ben Davis, and Yellow Transparent.

ENDURANCE OF TREES FROM BUDS GROUPED ACCORDING TO LOCATION ON TREE

The endurance of grafted buds having been considered as expressed in percentage of living trees, when grouped by varieties, examination may now be made of the behavior of the same selected buds as expressed when grouped according to location on tree. Using the five varieties represented in each of the three series propagated by grafting, the aggregate of buds selected was 1,180. The number represented by living trees at the end of the first year was 670, or 57 percent, and in the fall of 1915 there remained 430 living trees, which represented 36.5 percent of the buds selected. In Table 7 are shown the number of living trees arranged according to location of the buds from which they were propagated.

Here trees from buds from short interior branches led by a small margin in percentage of trees living. After eight years the percentage of trees living in this group was 44.28, followed by trees from top central buds with 43.84 percent living; trees from extreme lateral buds on north side came next with 34.61 percent living; then came the group of trees from extreme lateral buds on south side with 31.15 percent living, and last trees from buds from water sprouts with 27.36

percent living. Considering the four series separately, the groups of trees in no two series had the same order of ascendency in this matter of percentage of living trees. Trees from top central buds occupied first place in three series and took third place in the fourth; trees from extreme lateral buds from south side had second place in one, third place in two, and fourth place in one; trees from extreme lateral buds from north side had third place in two and fourth in two; trees from buds from short interior branches had first place in one, second place in two, and third place in one; while trees from buds from water sprouts occupied second place in one, fourth place in one, and fifth place in two. Of the five locations from which buds were chosen, buds from no one location produced trees that exhibited any marked or constant advantage over others in percentage of living trees at the end of eight years.

TABLE 7.—ENDURANCE OF TREES FROM BUDS GROUPED ACCORDING TO LOCATION ON TREE

Location of buds	No. of buds selected	Trees living fall of first year		Trees living after eight years	
		Number	Percentage	Number	Percentage
Top central..........	260	162	62.30	114	43.84
Lateral south........	260	140	53.84	81	31.15
Lateral north........	260	135	51.92	90	34.61
Short interior........	210	139	66.19	93	44.28
Water sprouts.......	190	94	49.47	52	27.36

GROWTH THE ONLY BASIS FOR COMPARISON

For determination of possible differences between trees produced from buds from different locations on the tree, the only available basis is the recorded measurements of yearly increments, or better, because more practicable, the two dimensions indicated by total height and spread. When this test was begun it was proposed to measure and record all growth made by each tree. The sum of growth of leader and of all lateral shoots was recorded as the growth of the tree for the particular year. This plan was carried out for two seasons with each series, but the impracticability of the method soon became apparent. Each additional year multiplied the number of shoots and the labor involved in making the measurements soon made a change of plan imperative. For the third season of the experiment, only the growth of the leader of each tree was recorded. At this stage another factor came in to modify greatly the form and dimensions of trees. Pruning became a necessity in order to insure future symmetry and correct habit of trees. Most trees required removal of branches to enable formation of the head at proper height. Some demanded cutting back of too vigorous leaders, and in the interest of symmetry, rampant laterals required shortening. Application of this treatment, looking to good form, was in most cases coincident with removal from nursery to orchard where the trees are planted 15 by 15 feet to remain until the end of the test. After planting in orchard, four measurements,—namely, total height, spread, and diameter and length of trunk, were recorded, together with notes regarding the amount of branching and general vigor. Without going into details of the measurements of each year, data showing the height and spread of the five varieties having representation in the three grafted series are given as recorded at the end of the season of 1915, segregating these series because of age differences (Table 8).

TABLE 8.—LOCATION OF BUD ON TREE: SHOWING GROWTH OF TREES, BY VARIETIES, FALL OF 1915

Variety	No. of trees	Average (inches)	
		Height	Spread
The 2,000 Series, Trees Eight Years Old			
Ben Davis	35	110.08	90.65
Winesap	25	110.68	97.32
Oldenburg	28	112.60	58.85
Yellow Transparent	14	92.00	37.42
Grimes	31	106.90	89.87
The 9,000 Series, Trees Six Years Old			
Ben Davis	53	81.73	54.05
Winesap	39	86.74	57.43
Oldenburg	47	83.08	39.46
Yellow Transparent	22	74.77	25.95
Grimes	90	85.85	65.51
The 12,000 Series, Trees Five Years Old			
Ben Davis	8	62.62	34.30
Winesap	14	64.21	38.07
Oldenburg	8	57.25	25.12
Yellow Transparent	9	57.55	12.44
Grimes	15	52.60	35.40
Combining the three series, ignoring age differences, the varieties range as below:			
Ben Davis	96	90.47	64.21
Winesap	78	90.37	72.00
Oldenburg	83	101.39	44.63
Yellow Transparent	45	78.91	26.82
Grimes	136	86.98	67.74

In both height and spread Ben Davis was slightly in advance of Grimes, but the differences were no greater than would be expected between varieties following their normal characteristics. Oldenburg and Yellow Transparent showed less spread than the other varieties because of the naturally more erect habit.

Arranging the 438 trees of these five varieties according to the locations from which the buds were taken and segregating the three series as before, the tabulation showing number of trees and average height and spread appears in Table 9.

TABLE 9.—LOCATION OF BUD ON TREE: SHOWING GROWTH OF TREES OF THE FIVE VARIETIES, BY SERIES, FALL OF 1915

Location of buds	2,000 series			9,000 series			12,000 series		
	No. of trees	Average (inches)		No. of trees	Average (inches)		No. of trees	Average (inches)	
		Height	Spread		Height	Spread		Height	Spread
Top central	39	110.82	84.87	64	84.95	55.00	10	58.50	23.00
Lateral south	21	108.00	71.23	57	84.56	55.33	11	56.63	28.09
Lateral north	30	105.60	72.36	56	84.71	55.19	4	61.25	39.25
Short interior	25	112.08	84.24	56	82.60	56.35	14	60.14	28.00
Water sprouts	18	100.83	75.22	18	80.98	49.83	15	58.66	37.53

Reducing this tabulation to a single expression by combining the trees of different ages, in order to facilitate comparison of growth from buds from the different locations, Table 10 is given as a condensed result of the last measurements made.

TABLE 10.—LOCATION OF BUD ON TREE: COMPARISON OF GROWTH OF TREES OF THE THREE SERIES COMBINED, AS MEASURED IN THE FALL OF 1915

Location of buds	No. of trees	Average (inches)	
		Height	Spread
Top central	113	91.54	62.47
Lateral south	89	86.64	55.71
Lateral north	90	90.63	60.21
Short interior	95	87.05	59.51
Water sprouts	51	81.41	55.17

The foregoing gives the results to November, 1915, for five of the varieties in the three series propagated by grafting and points to a close approximation in the development of trees from buds from the different locations. Tabulations in detail for each variety show no regularity in sequence of locations when arranged in order on the basis of total height of the trees. In some cases trees from buds from short interior branches showed greatest growth, in others trees from buds from water sprouts were in ascendency, and in still others the trees from buds from central terminal shoots had first place. In no case, however, was there any marked or significant departure from the general trend shown by the trees when grouped either by varieties or by the locations from which buds were taken. The cases of maximum departures from the general average were with single varieties, in single series, where the number of trees was small. Grouping single varieties within a series, or combining the series, either by varieties or by bud location, has immediate effect in smoothing out and bringing growth curves into close approximation. In all computations the effect of numbers is strikingly shown, and apparently it would require only small additions to bring the results to absolute zero, thus demonstrating conclusively that for purposes of propagation it makes no difference from what position on the tree the bud is taken.

To illustrate further the results of this test of buds from different locations, the following tabulations and graphs are presented. Each tabulation with its accompanying graph stands for one complete series in which the trees were of equal age. In Table 11 is presented the growth record for eight years for the 2,000 series, which included five varieties, and in Fig. 13 the same data are presented graphically. It would be more satisfactory and the curves in all probability would be more nearly coincident if the numbers of trees for the various locations were equal, but even as it is there is remarkable uniformity in the development of the trees from buds from the different locations. The 7,000 series, propagated, as already explained, by budding, and including six varieties, sustained such heavy losses that the number of trees remaining was too small for satisfactory comparison; however, even here the departures from the general trend of development were not great, as is shown in Table 12 and in Fig. 14. The 9,000 series included twelve varieties and was started with 840 selected buds; Table 13 and Fig. 15 show the growth for six seasons of the 436 remaining trees. Greater uniformity in the distribution of trees in location groups would doubtless have given curves that more nearly coincided, but as it is, there is close approximation in the growth of the different groups. The 12,000 series began with 530 buds distributed among eleven varieties; in Table 14 and in Fig. 16 are given the growth records of 146 trees for five years, and here there is shown a more nearly equal distribution in the location groups.

Figs. 17 to 32 illustrate some of the trees of the 2,000 series, testing buds from different locations on the tree. These plates are all from photographs made in July, 1915.

TABLE 11.—LOCATION OF BUD ON TREE: 2,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1908	1909	1910	1911	1912	1913	1914	1915
Top Central: Average of 39 Trees								
Height	20	18	10	44	54	68	84	111
Spread	..	..	..	..	30	44	58	85
Lateral South Side: Average of 21 Trees								
Height	18	21	10	43	52	67	85	108
Spread	..	..	..	..	24	36	50	70
Lateral North Side: Average of 30 Trees								
Height	18	17	9	41	52	66	82	105
Spread	..	..	..	..	25	36	47	71
Short Interior: Average of 25 Trees								
Height	18	16	9	42	53	69	87	112
Spread	..	..	..	..	28	42	56	84
Water Sprouts: Average of 18 Trees								
Height	18	15	9	39	51	64	79	101
Spread	..	..	..	..	25	39	65	75

NOTE.—Total growth is recorded for 1908 and 1909, for 1910 length of leader only, and for each succeeding year total height of tree.

TABLE 12.—LOCATION OF BUD ON TREE: 7,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1910	1911	1912	1913	1914	1915
Top Central: Average of 7 Trees						
Height	21	7	41	51	63	86
Spread	..	..	..	17	33	57
Lateral South Side: Average of 5 Trees						
Height	30	7	43	52	66	92
Spread	..	..	..	22	35	63
Lateral North Side: Average of 4 Trees						
Height	24	6	40	54	69	94
Spread	..	..	..	26	43	74
Short Interior: Average of 4 Trees						
Height	21	4	35	46	65	85
Spread	..	..	..	16	29	49
Water Sprouts: Average of 3 Trees						
Height	25	8	43	47	60	85
Spread	..	..	..	14	36	67

NOTE.—Total growth is recorded for 1910, for 1911 length of leader only, and for each succeeding year total height of tree.

TABLE 13.—LOCATION OF BUD ON TREE: 9,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1910	1911	1912	1913	1914	1915
Top Central: Average of 112 Trees						
Height	19	9	41	49	64	88
Spread	..	..	..	21	31	60
Lateral South Side: Average of 102 Trees						
Height	18	10	41	49	65	88
Spread	..	..	..	18	29	65
Lateral North Side: Average of 92 Trees						
Height	16	11	41	50	63	87
Spread	..	..	..	16	30	58
Short Interior: Average of 84 Trees						
Height	15	12	36	44	60	83
Spread	..	..	..	17	30	55
Water Sprouts: Average of 46 Trees						
Height	16	10	36	46	60	82
Spread	..	..	..	15	29	59

NOTE.—Total growth is recorded for 1910, for 1911 length of leader only, and for each succeeding year total height of tree.

TABLE 14.—LOCATION OF BUD ON TREE: 12,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1911	1912	1913	1914	1915
Top Central: Average of 26 Trees					
Height	7	17	25	37	56
Spread	..	..	..	9	26
Lateral South Side: Average of 29 Trees					
Height	8	18	24	36	60
Spread	..	..	..	12	32
Lateral North Side: Average of 29 Trees					
Height	9	18	28	42	65
Spread	..	..	..	12	34
Short Interior: Average of 28 Trees					
Height	10	18	29	41	64
Spread	..	..	..	12	34
Water Sprouts: Average of 34 Trees					
Height	9	19	30	41	64
Spread	..	..	..	15	38

NOTE.—Measurement for 1911 is given for length of leader only; for each succeeding year total height of tree is given.

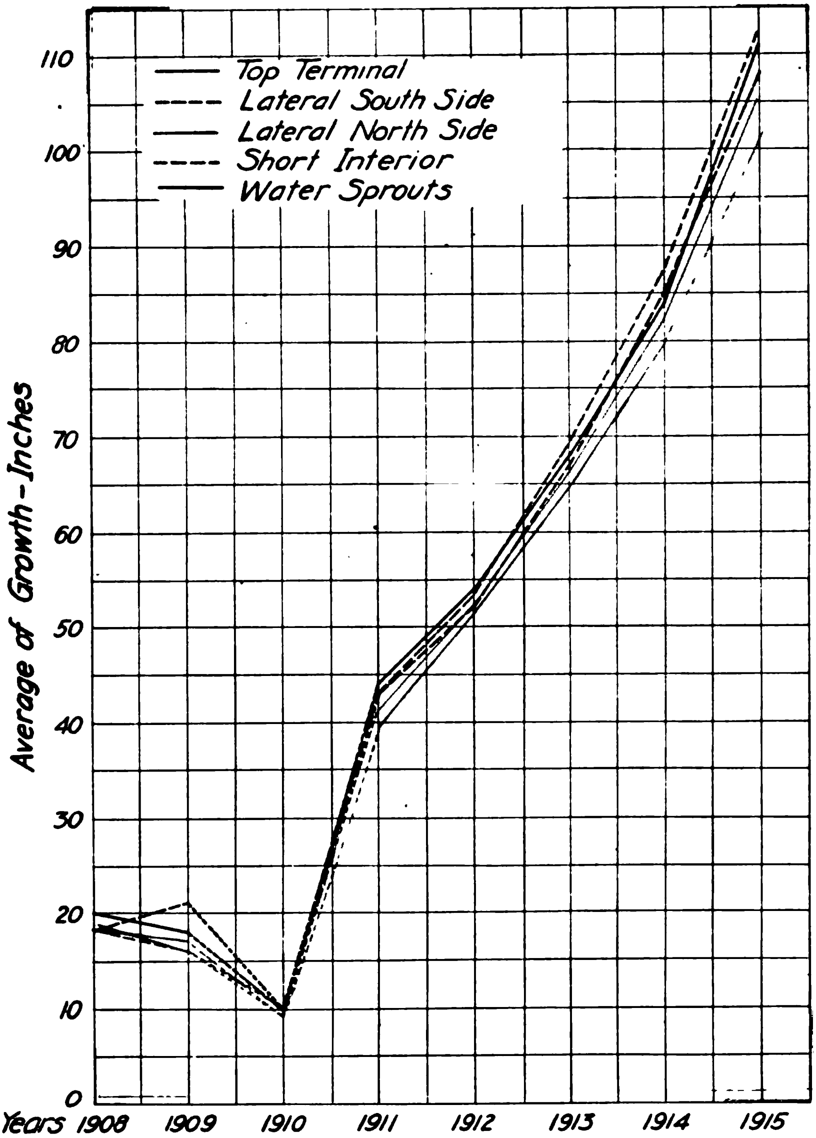

FIG. 13.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON TREE: ALL VARIETIES COMBINED, 2,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

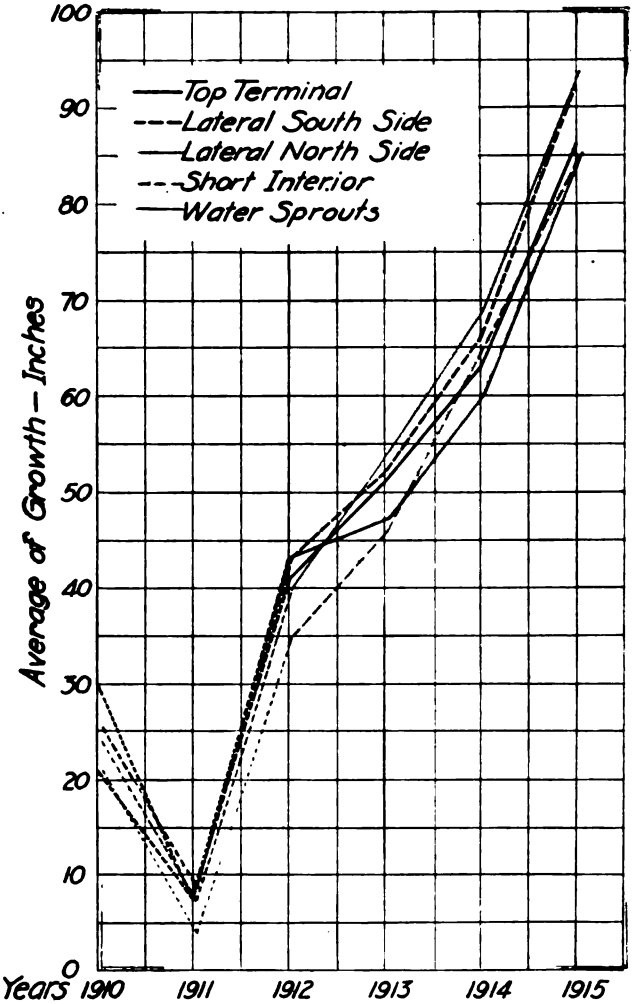

FIG. 14.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON TREE: ALL VARIETIES COMBINED, 7,000 SERIES

Growth in 1910 was measured by the sum of lengths of leader and branches, in 1911 by the length of leader only, and in 1912 to 1915 by the total height.

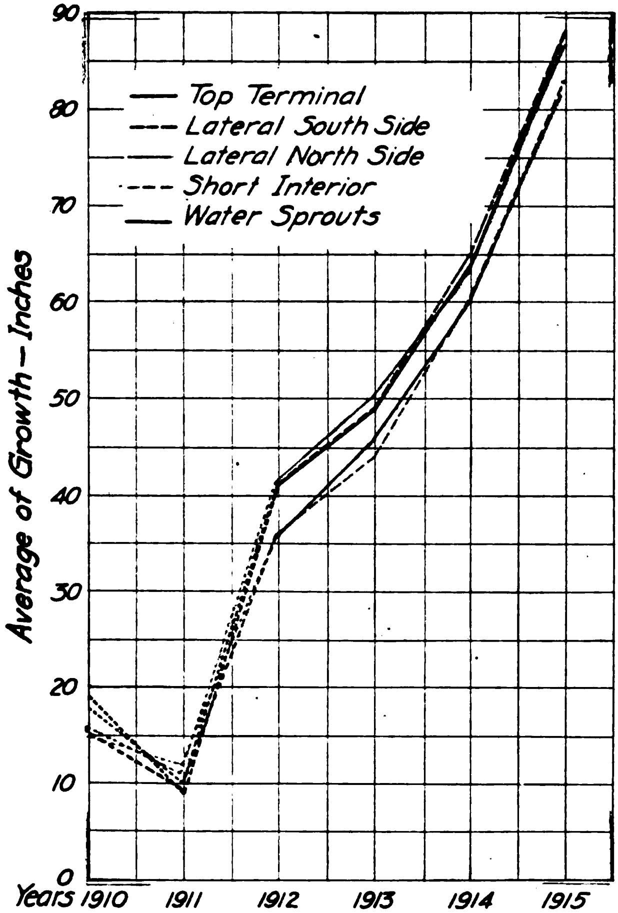

FIG. 15.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON TREE: ALL VARIETIES COMBINED, 9,000 SERIES

Growth in 1910 was measured by the sum of lengths of leader and branches, in 1911 by the length of leader only, and in 1912 to 1915 by the total height.

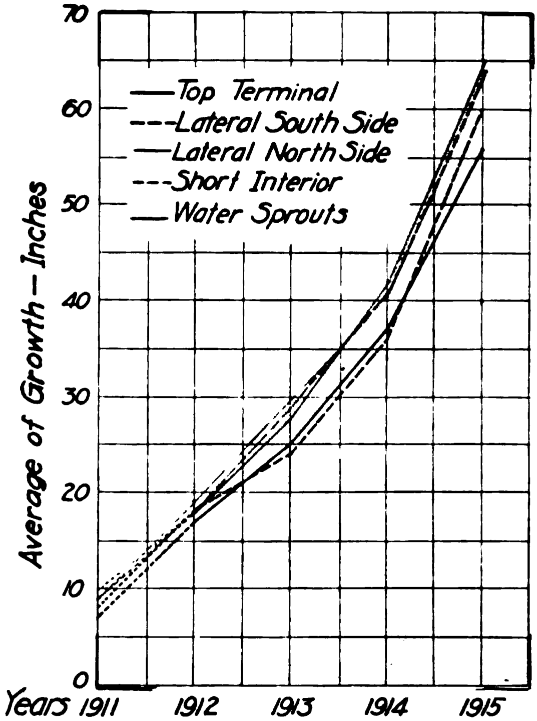

FIG. 16.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON THE TREE: ALL VARIETIES COMBINED, 12,000 SERIES

Growth in 1911 was measured by the length of leader only, and in 1912 to 1915 by the total height.

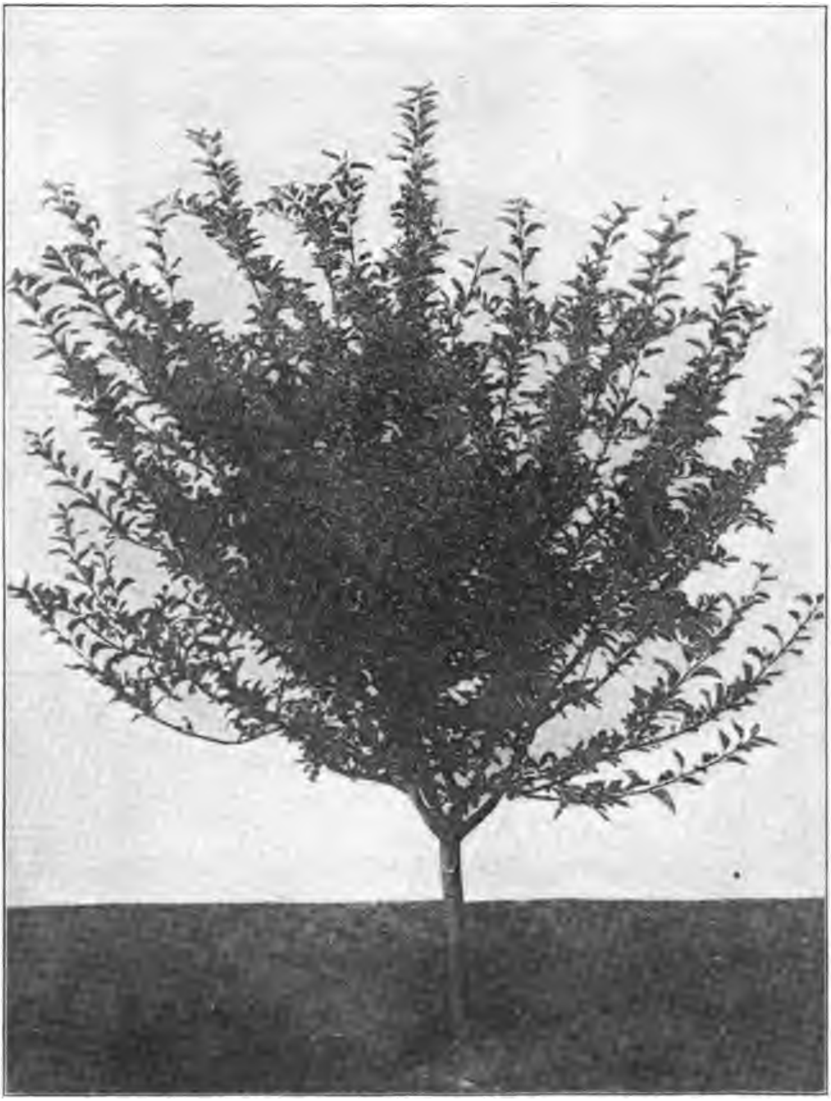

FIG. 17.—NO. 2451: GRIMES FROM TOP TERMINAL BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET, 2 INCHES

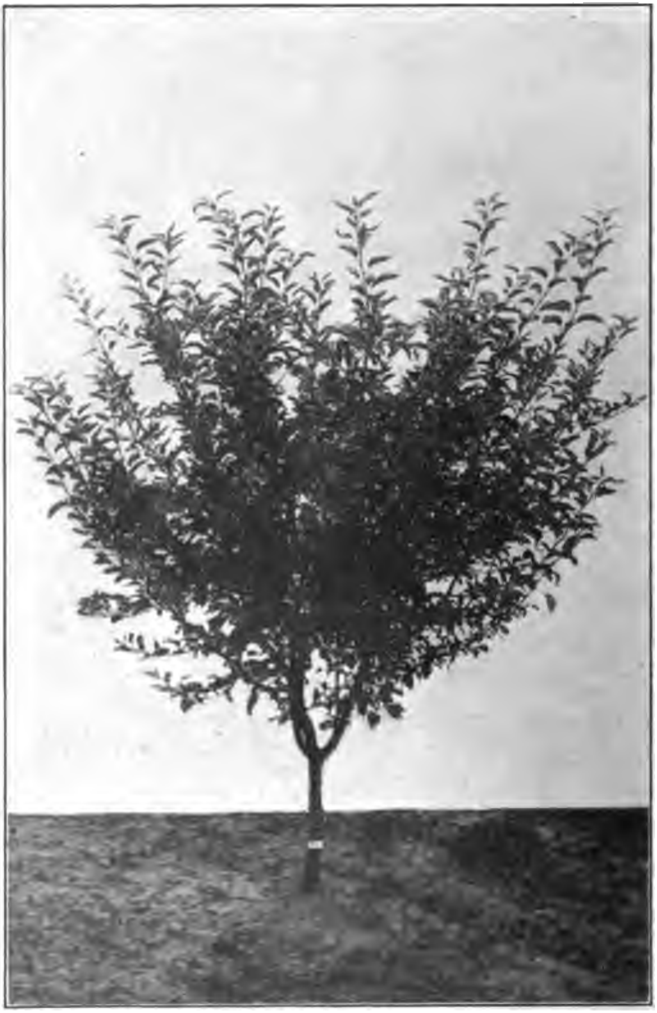

FIG. 18.—NO. 2218: GRIMES FROM SOUTH LATERAL BUD
HEIGHT, OCTOBER 13, 1915, 9 FEET, 6 INCHES

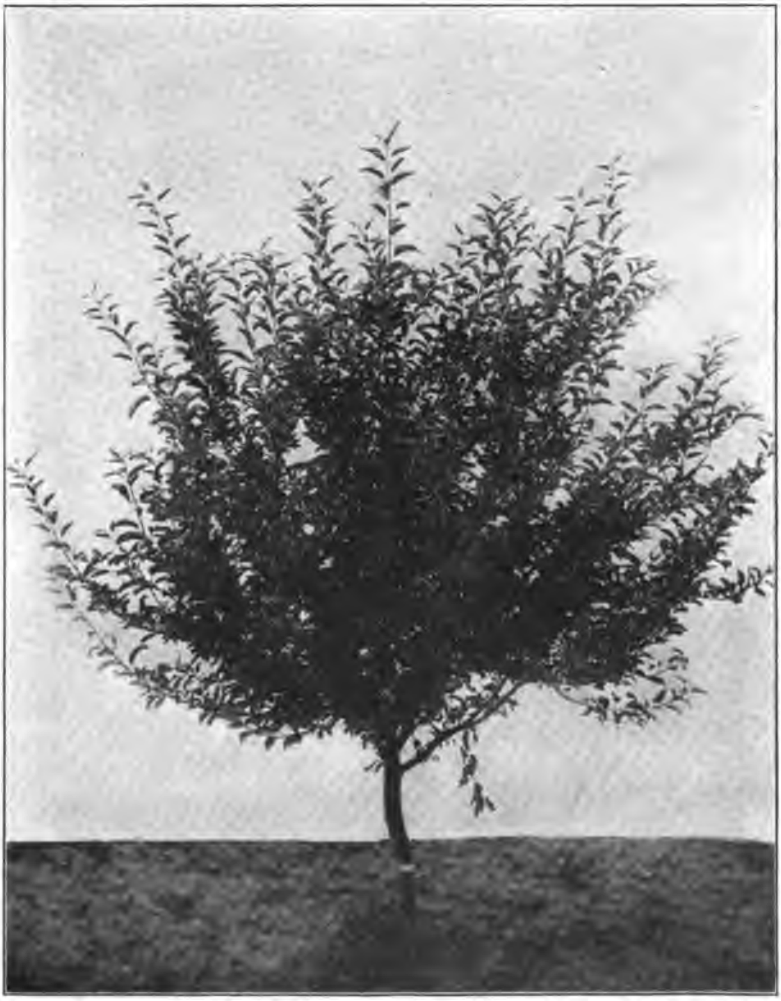

FIG. 19.—NO. 2229: GRIMES FROM NORTH LATERAL BUD
HEIGHT, OCTOBER 13, 1915, 9 FEET, 9 INCHES

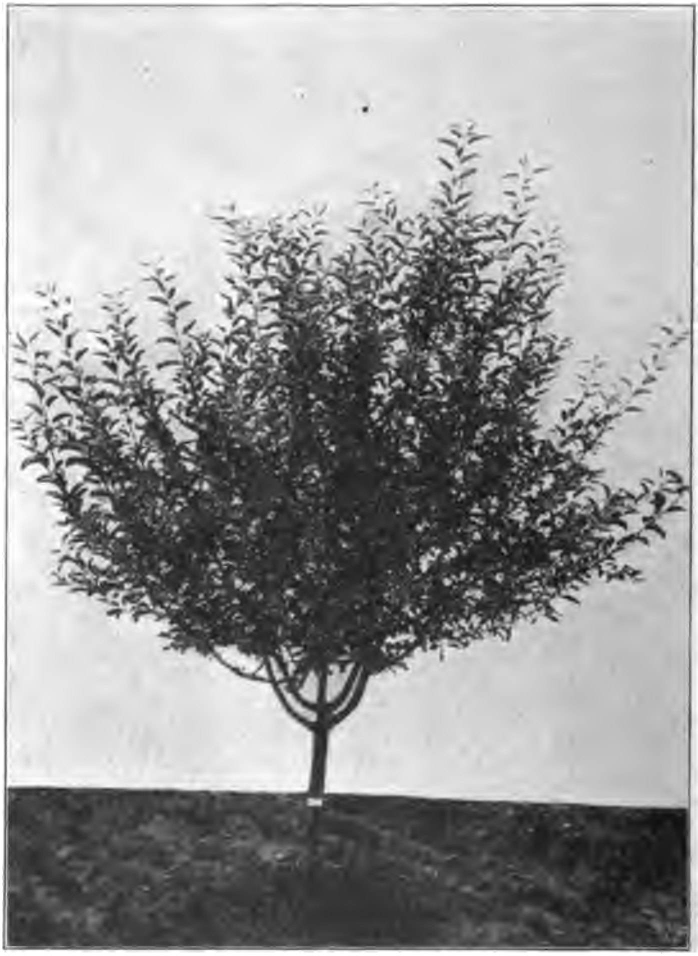

FIG. 20.—NO. 2235: GRIMES FROM BUD FROM SHORT INTERIOR BRANCH
HEIGHT, OCTOBER 13, 1915, 9 FEET, 1 INCH

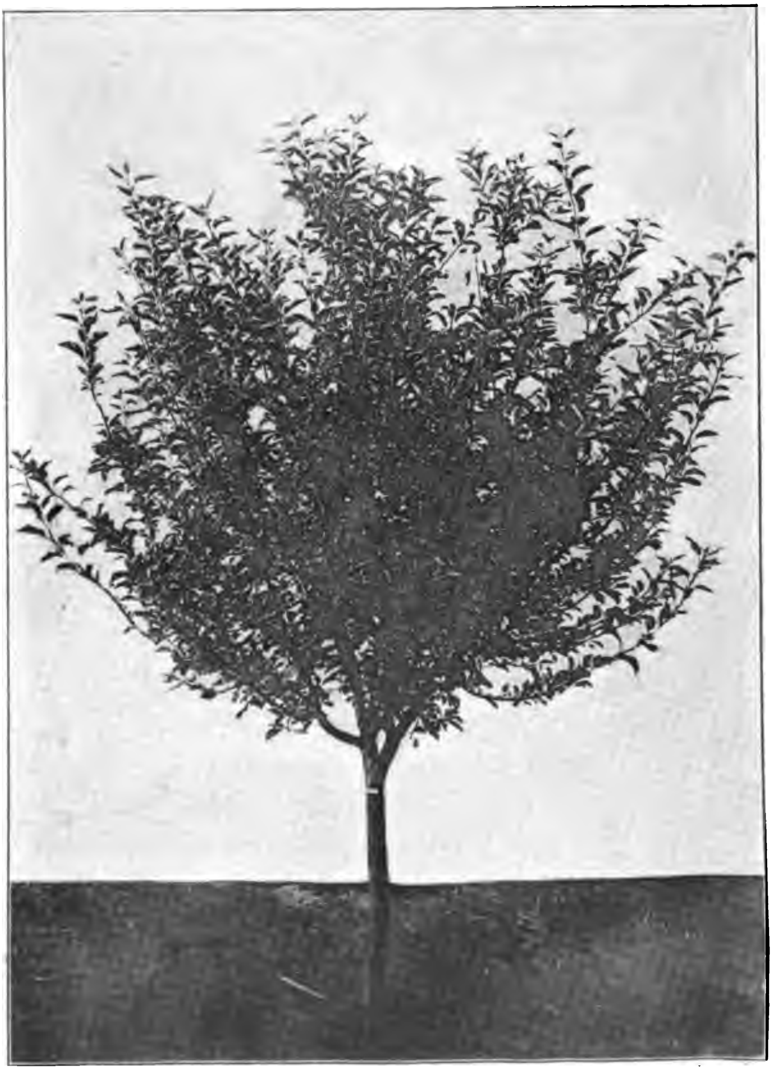

FIG. 21.—No. 2247: GRIMES FROM BUD FROM WATER SPROUT
HEIGHT, OCTOBER 13, 1915, 9 FEET, 11 INCHES

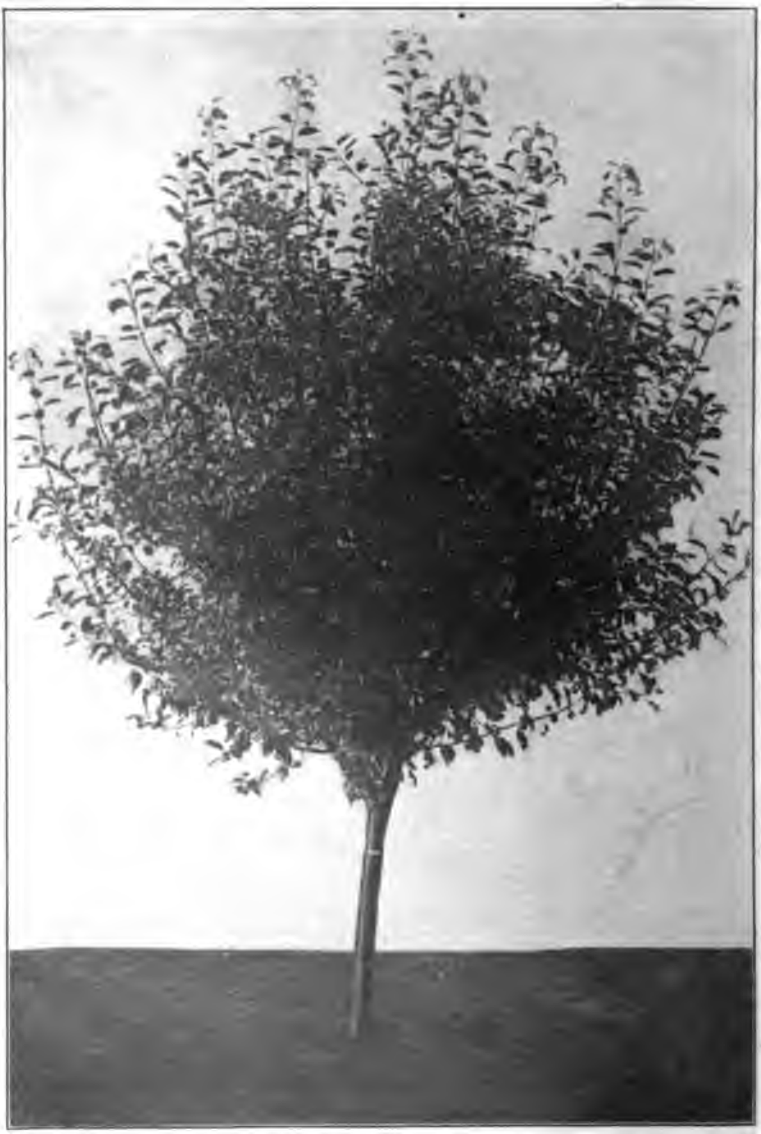

FIG. 22.—NO. 2009: BEN DAVIS FROM TOP TERMINAL BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET, 6 INCHES

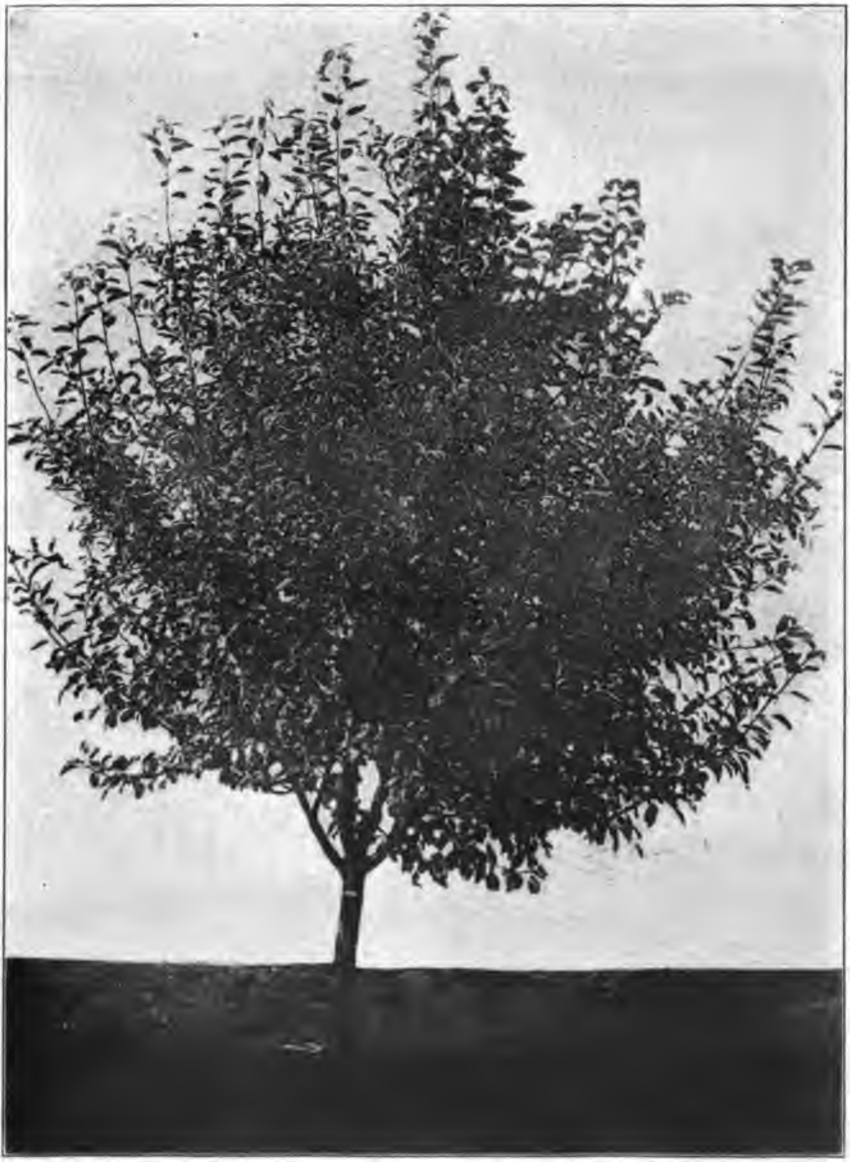

FIG. 23.—NO. 2016: BEN DAVIS FROM SOUTH LATERAL BUD
HEIGHT, OCTOBER 13, 1915, 11 FEET, 2 INCHES

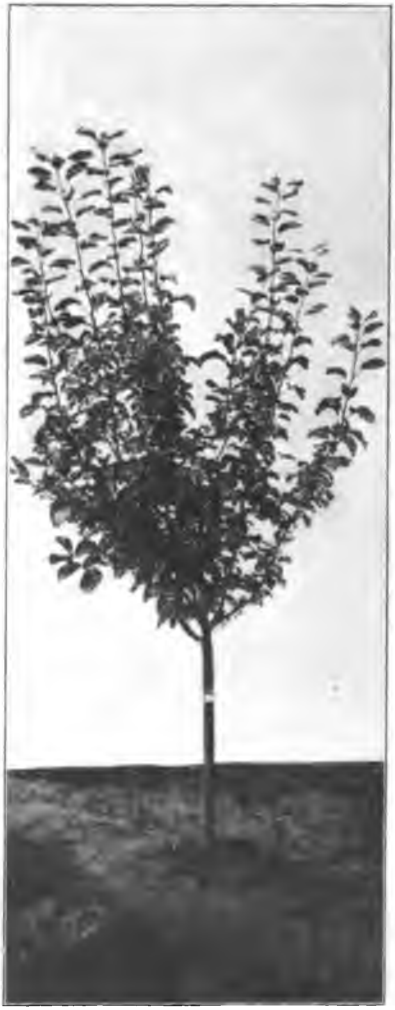

FIG. 24.—NO. 2109: OLDENBURG FROM TOP TERMINAL BUD
HEIGHT, OCTOBER 13, 1915, 8 FEET, 3 INCHES

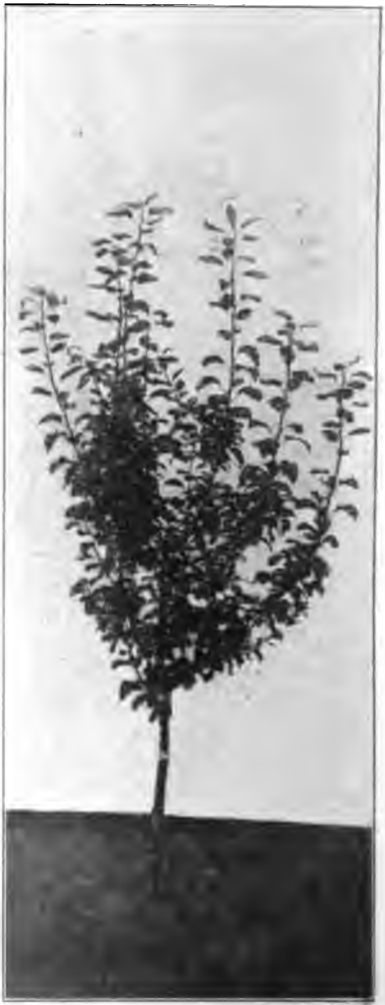

FIG. 25.—NO. 2111: OLDENBURG FROM SOUTH LATERAL BUD
HEIGHT, OCTOBER 13, 1915, 8 FEET

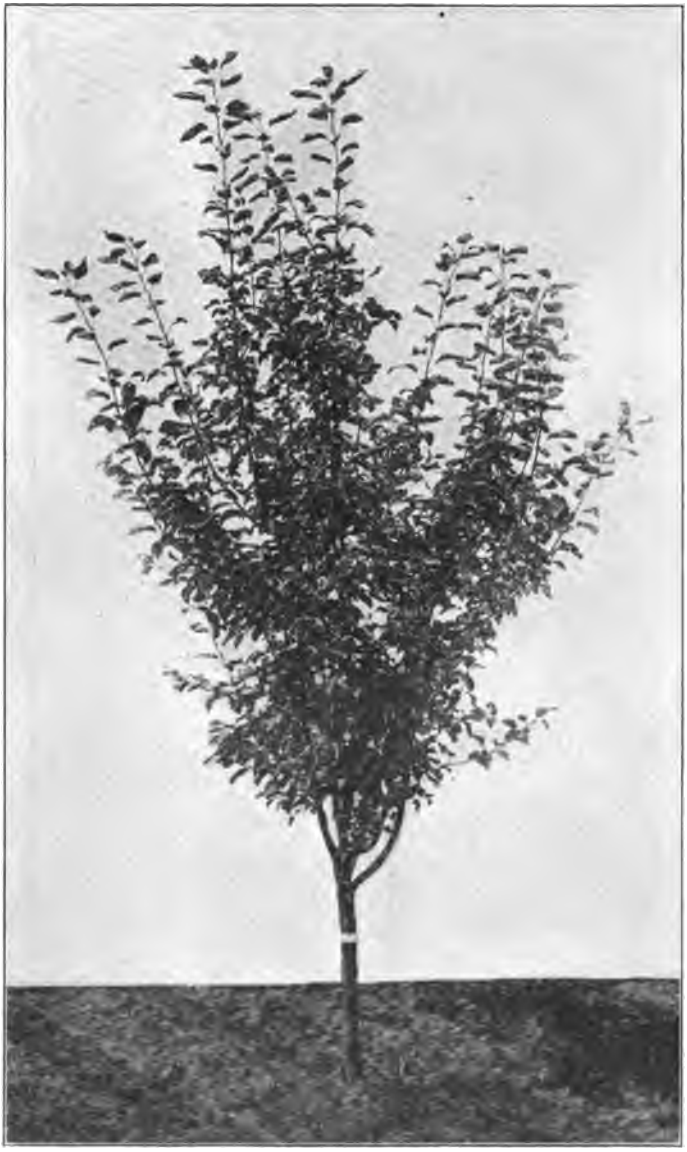

FIG. 26.—NO. 2122: OLDENBURG FROM NORTH LATERAL BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET, 5 INCHES

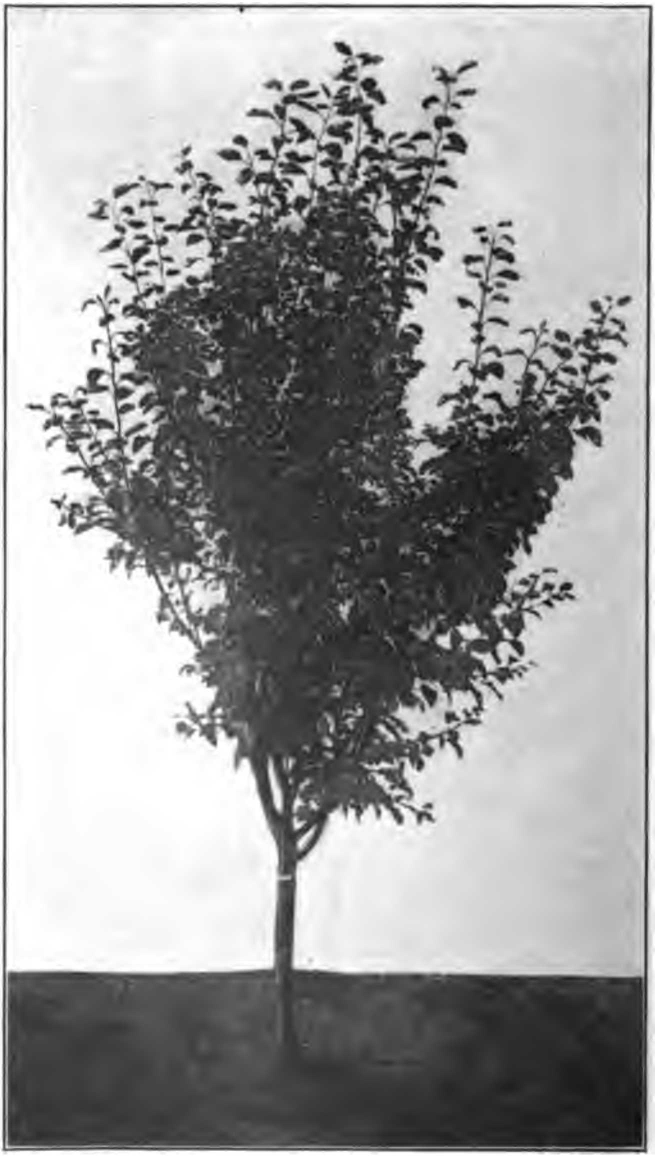

FIG. 27.—NO. 2137: OLDENBURG FROM BUD FROM SHORT INTERIOR BRANCH HEIGHT, OCTOBER 13, 1915, 10 FEET, 9 INCHES

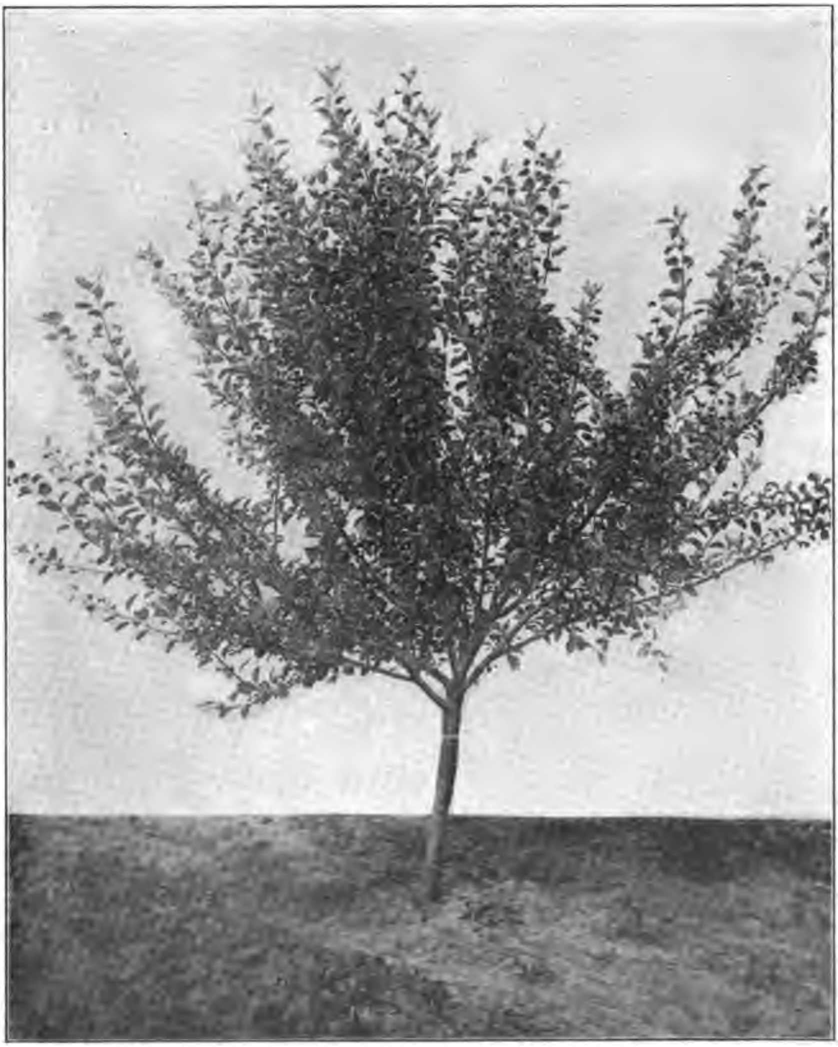

FIG. 28.—NO. 2052: WINESAP FROM TOP TERMINAL BUD
HEIGHT, OCTOBER 13, 1915, 9 FEET, 11 INCHES

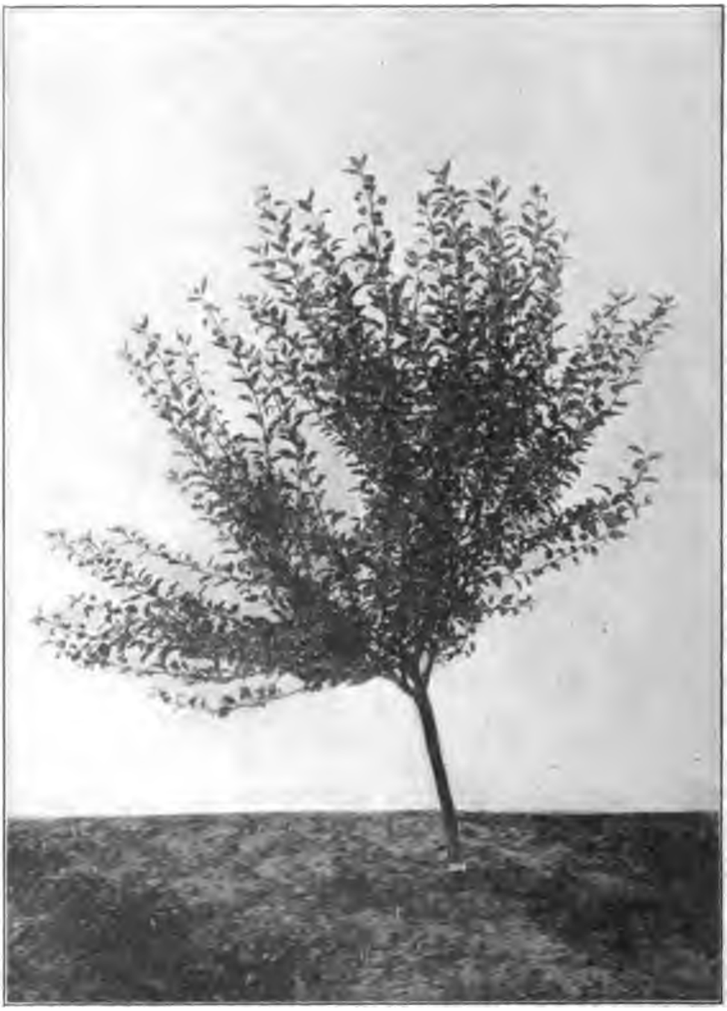

FIG. 29.—NO. 2363: WINESAP FROM SOUTH LATERAL BUD
HEIGHT, OCTOBER 13, 1915, 8 FEET, 8 INCHES

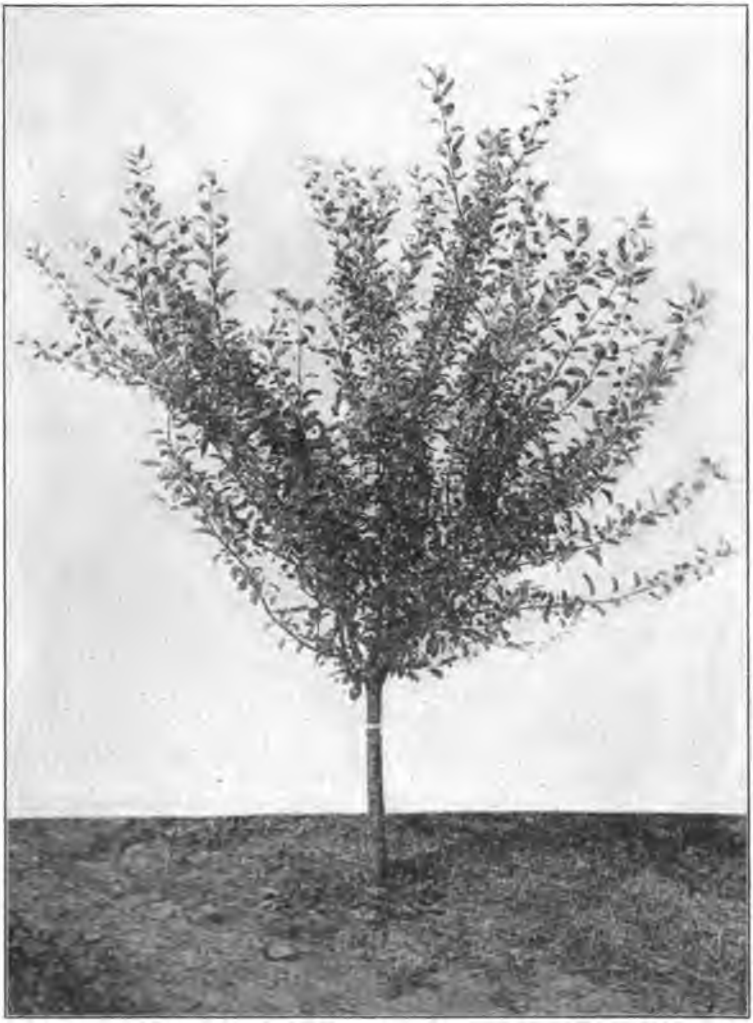

FIG. 30.—NO. 2078: WINESAP FROM NORTH LATERAL BUD
HEIGHT, OCTOBER 13, 1915, 8 FEET, 5 INCHES

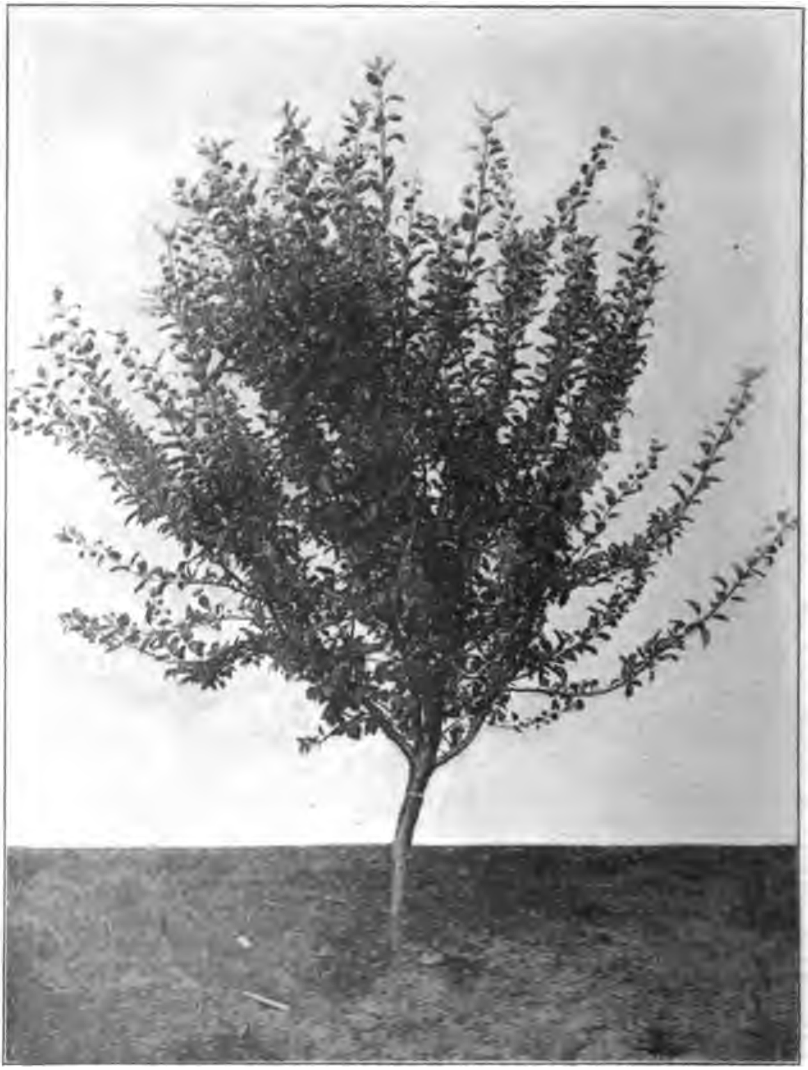

FIG. 31.—NO. 2087: WINESAP FROM BUD FROM SHORT INTERIOR BRANCH
HEIGHT, OCTOBER 13, 1915, 9 FEET, 9 INCHES

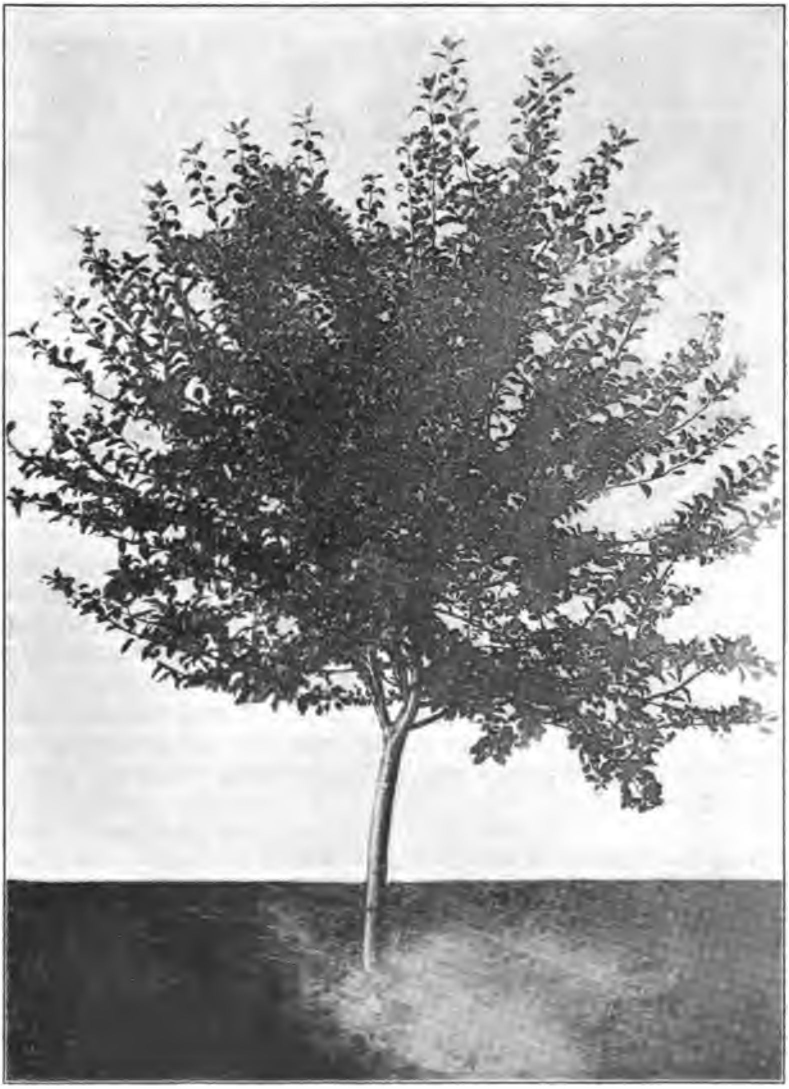

FIG. 32.—NO. 2393: WINESAP FROM BUD FROM WATER SPROUT
HEIGHT, OCTOBER 13, 1915, 10 FEET, 7 INCHES

Comparative Value of Buds from Different Locations on Shoot

The third division of the bud-selection project is a test for differences in value, for purposes of propagation, of buds from different locations on the same shoot. Four locations are represented; namely, terminal buds, lateral buds at distal end of shoot, buds from middle of shoot, and buds from near the base of the shoot. As in the other divisions of the project, selections were made in series, extending over the four years 1908 to 1911. In three of the series propagation was by grafting. The 8,000 series of 1909 was propagated by budding in August of that year. The number of buds selected and their distribution as to location are given in Table 15.

Table 15.—Location of Bud on Shoot: Showing Distribution of Buds Selected

Series	Year	Number of buds				
		Terminal	Lateral at distal end	Middle	Near base	Total
3 000	1908	80	80	80	80	320
8 000	1909	10	60	60	60	190
10 000	1910	..	150	150	150	450
13 000	1911	110	...	110	110	330
	Total	200	290	400	400	1 290

Fifteen varieties were represented. Ben Davis, Winesap, Oldenburg, Yellow Transparent, and Grimes appeared in all series; the other ten varieties appeared in one or both of the 10,000 and the 13,000 series. Here, as in the test of location of buds on trees, many chosen buds failed to grow and some of those starting were lost thru accidents, so that the number of trees living in the fall of 1915 was much below the number of buds selected. Living trees classified according to the locations from which buds were taken for each series are given in Table 16.

Table 16.—Location of Bud on Shoot: Showing Distribution of Trees Living in 1915

Series	Number of trees				Age of trees (years)
	Terminal	Lateral at distal end	Middle	Near base	
3 000	23	29	17	26	8
8 000	...	10	12	6	6
10 000	..	64	74	48	6
13 000	36	..	24	15	5

Of the 384 trees living in 1915, about 25 percent were eight years old, nearly 56 percent were six years old, and about 20 percent were five years old. Of the five varieties represented in all series, Ben Davis stood first in percentage of living trees with a percentage of 41. Grimes followed with 32.5 percent, Winesap with 29 percent, Oldenburg with

20 percent, and Yellow Transparent with a little less than 18 percent. Arranging the trees of these five varieties according to the locations from which the buds were taken, it appears that, with Ben Davis and Winesap, the highest percentage of trees surviving was with those from lateral buds from the distal ends of shoots; with Oldenburg and Yellow Transparent the highest percentage was with those from buds from the middle of shoots; while with Grimes the trees from terminal buds survived in greatest numbers.

In general, the losses of trees from selected buds were greater with terminal buds and those near the base than with buds taken from central and distal portions of shoots. There appears no evident reason why losses should be greater with terminal buds than with central buds or lateral buds from the distal end; they were, in general, larger than buds from other situations, and so far as could be judged from external appearances, perfectly sound and healthy. It is possible that winter injury occurred sufficient to prevent growth, but insufficient to be externally apparent; this does not seem probable, however, because no general failure of terminal buds on trees from which buds were selected was observed. No wholly satisfactory reason for the failures that occurred suggests itself, but it is a fact that an unexpectedly large percentage of terminal buds failed to grow.

In selecting buds near the bases of shoots, effort was made to take them from as near the base as possible and yet to preserve sufficient scion length for grafting. Scions were made as short as possible, varying from two to four inches according to the length of the shoot. These basal scions were often of greater diameter than is desirable in scions. They were short, rigid, and often curved, and were adjusted to stocks with difficulty, and were easily displaced. It is probable, therefore, that a considerable portion of the losses in this group of buds should be ascribed to imperfections in the mechanical operations of grafting. However, observations upon the starting of grafts representing the four groups of buds convince the writer that buds near the bases of shoots do not start as readily nor as vigorously as do buds from the central portion of the shoot; neither do they equal in vigor of initial growth those lateral buds situated just below the terminal, altho this tardy and often weak start is in no sense a measure of subsequent growth.

GROWTH OF TREES

Measurements of growth of trees in this test of buds from different locations on the shoot were taken in the same manner and on the same dates as were those in the test of buds from different locations on the tree. Comparing the measurements made in 1915, there appear the same irregularities in sequence of groups, when arranged in order of merit, and the same close approximations between the different groups under test, as were found in the groups from buds from different locations on the tree.

Examining the measurements by series and considering first the 3,000 series, trees eight years old, it appears that trees from buds from middle of shoot and from near the basal end were equal in height and stood first, followed in order by trees from lateral buds at distal end and trees from terminal buds.

The 8,000 series, with trees six years old, had no trees from terminal buds. Trees from buds near the base took precedence in height, followed by trees from buds near distal end, and then by trees from buds from middle of shoot.

In the 10,000 series, also with six-year-old trees, and also with no trees representing terminal buds, trees from buds from distal end took the lead in height, while those from buds near base and from middle of shoot were of equal height.

In the 13,000 series, with five-year-old trees, trees from buds near the basal end stood first in height, followed by trees from buds from middle of shoot and then by trees from terminal buds.

But in all of the four series no group of trees representing any one of the four locations had sufficient advantage in growth over other groups to make it stand out in any distinctive way. The differences were so insignificant as to encourage the belief that repetition of the work, or any moderate addition to the numbers of trees involved, would be quite likely to change or even to reverse entirely the sequence of greatest height. In Tables 17 to 20 are shown, by series, the averages of total growth by years for trees from buds from each location. In Figs. 33 to 36 these data are presented in graphic form.

Figs. 37 to 43 show individual trees of the 3,000 series testing buds from different locations on the shoot. All are from photographs made in July, 1915.

TABLE 17.—LOCATION OF BUD ON SHOOT: 3,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1908	1909	1910	1911	1912	1913	1914	1915
Terminal Buds: Average of 23 Trees								
Height................	18	19	10	40	48	60	75	98
Spread................	..	..	..	..	..	37	49	76
Lateral at Distal End: Average of 29 Trees								
Height................	20	17	10	42	52	65	78	102
Spread................	..	..	..	..	..	40	52	79
Middle of Shoot: Average of 17 Trees								
Height................	20	17	10	44	54	68	83	107
Spread................	..	..	..	..	..	47	56	82
Near Basal End: Average of 26 Trees								
Height................	19	18	10	49	59	70	82	107
Spread................	..	..	..	..	..	45	56	83

NOTE.—Total growth is recorded for 1908 and 1909, for 1910 length of leader only, and for each succeeding year total height of tree.

TABLE 18.—LOCATION OF BUD ON SHOOT: 8,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1910	1911	1912	1913	1914	1915
Lateral at Distal End: Average of 10 Trees						
Height.................	25	4	36	37	53	73
Spread	..	..	..	11	23	50
Middle of Shoot: Average of 12 Trees						
Height.................	18	5	33	39	51	68
Spread.................	..	..	..	11	24	39
Near Basal End: Average of 6 Trees						
Height.................	16	6	36	45	57	76
Spread.................	..	..	..	13	27	47

NOTE.—Total growth is recorded for 1910, for 1911 length of leader only, and for each succeeding year total height of tree.

TABLE 19.—LOCATION OF BUD ON SHOOT: 10,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1910	1911	1912	1913	1914	1915
Lateral at Distal End: Average of 64 Trees						
Height	20	5	39	49	60	82
Spread	..	..	..	16	29	57
Middle of Shoot: Average of 74 Trees						
Height	18	7	37	48	57	78
Spread	..	..	..	14	28	57
Near Basal End: Average of 48 Trees						
Height	21	7	37	48	57	78
Spread	..	..	..	15	28	58

NOTE.—Total growth is recorded for 1910, for 1911 length of leader only, and for each succeeding year total height of tree.

TABLE 20.—LOCATION OF BUD ON SHOOT: 13,000 SERIES, SHOWING GROWTH OF TREES OF ALL VARIETIES COMBINED

(Expressed in inches)

Year	1911	1912	1913	1914	1915
Terminal Buds: Average of 36 Trees					
Height..............	8	22	27	39	57
Spread..............	..	..	..	12	32
Middle of Shoot: Average of 24 Trees					
Height..............	9	20	30	38	60
Spread..............	..	..	..	12	34
Near Basal End: Average of 15 Trees					
Height..............	10	20	30	42	65
Spread..............	..	..	..	13	38

NOTE.—Length of leader only is recorded for 1911, and for each succeeding year total height of tree.

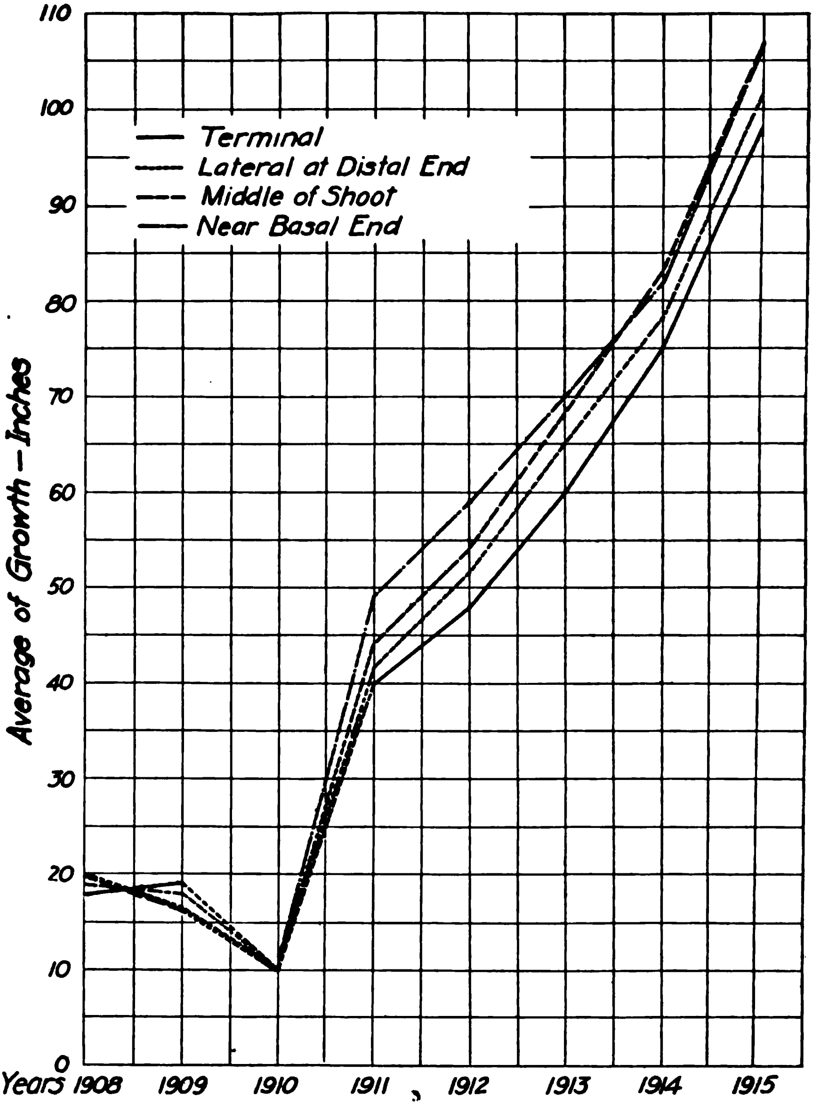

FIG. 33.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON THE SHOOT: ALL VARIETIES COMBINED, 3,000 SERIES

Growth in 1908 and 1909 was measured by the sum of lengths of leader and branches, in 1910 by the length of leader only, and in 1911 to 1915 by the total height.

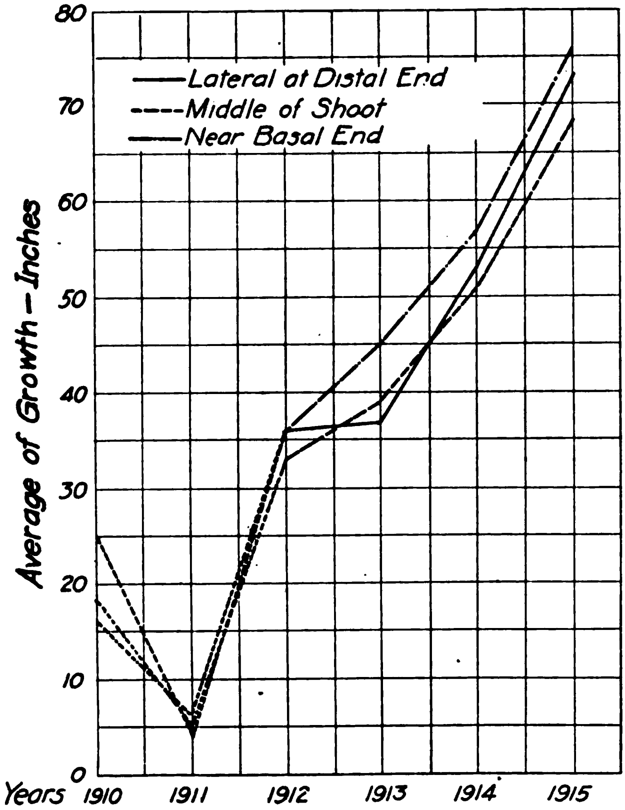

FIG. 34.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON THE SHOOT: ALL VARIETIES COMBINED, 8,000 SERIES

Growth in 1910 was measured by the sum of lengths of leader and branches, in 1911 by the length of leader only, and in 1912 to 1915 by the total height.

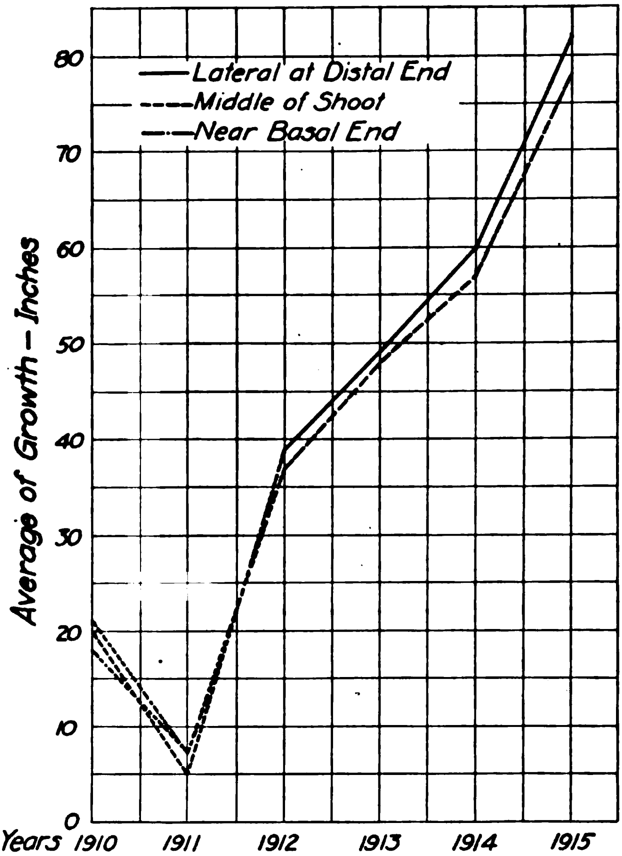

FIG. 35.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON THE SHOOT: ALL VARIETIES COMBINED, 10,000 SERIES

Growth in 1910 was measured by the sum of lengths of leader and branches, in 1911 by the length of leader only, and in 1912 to 1915 by the total height.

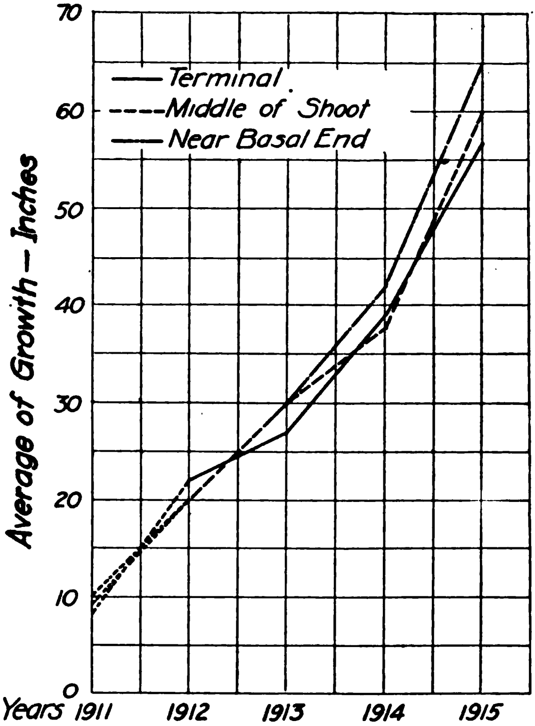

FIG. 36.—SHOWING THE GROWTH OF TREES FROM BUDS SELECTED FROM DIFFERENT LOCATIONS ON THE SHOOT: ALL VARIETIES COMBINED, 13,000 SERIES

Growth in 1911 was measured by the length of leader only, and in 1912 to 1915 by the total height.

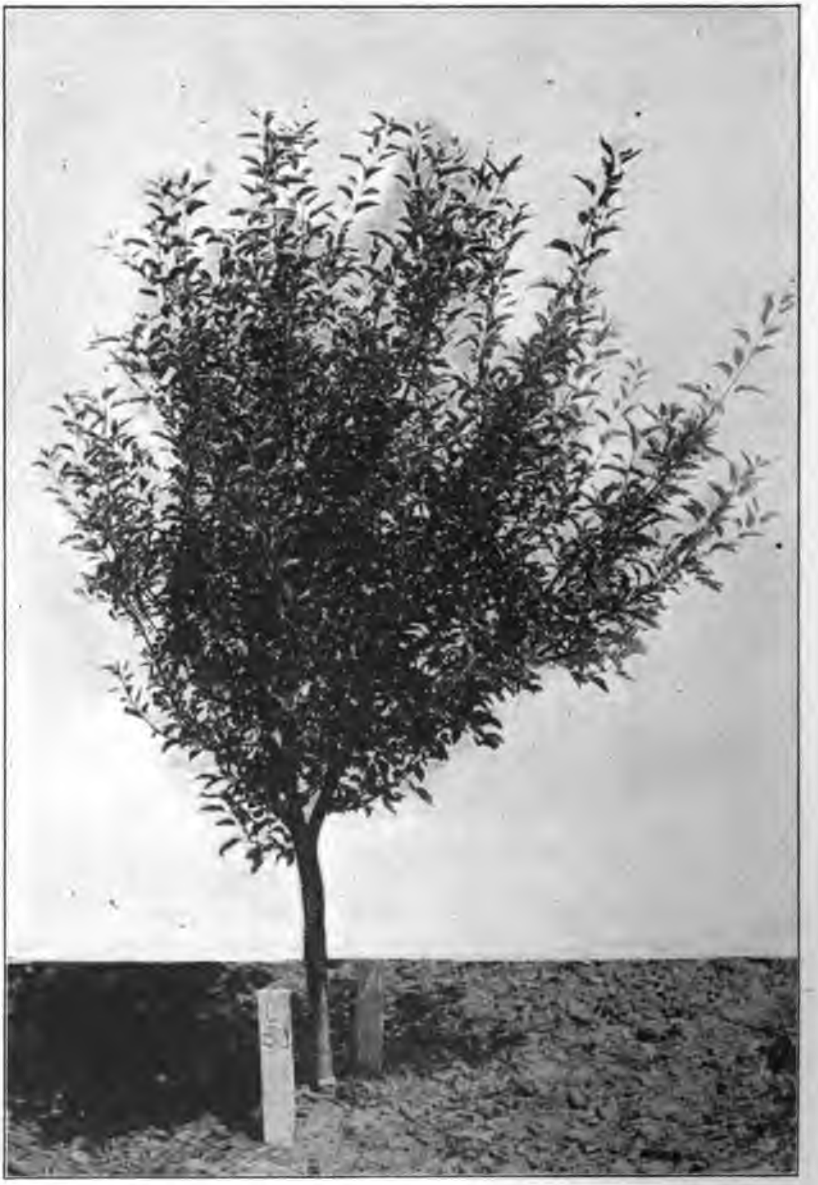

FIG. 37.—NO. 3170: GRIMES FROM TERMINAL BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET

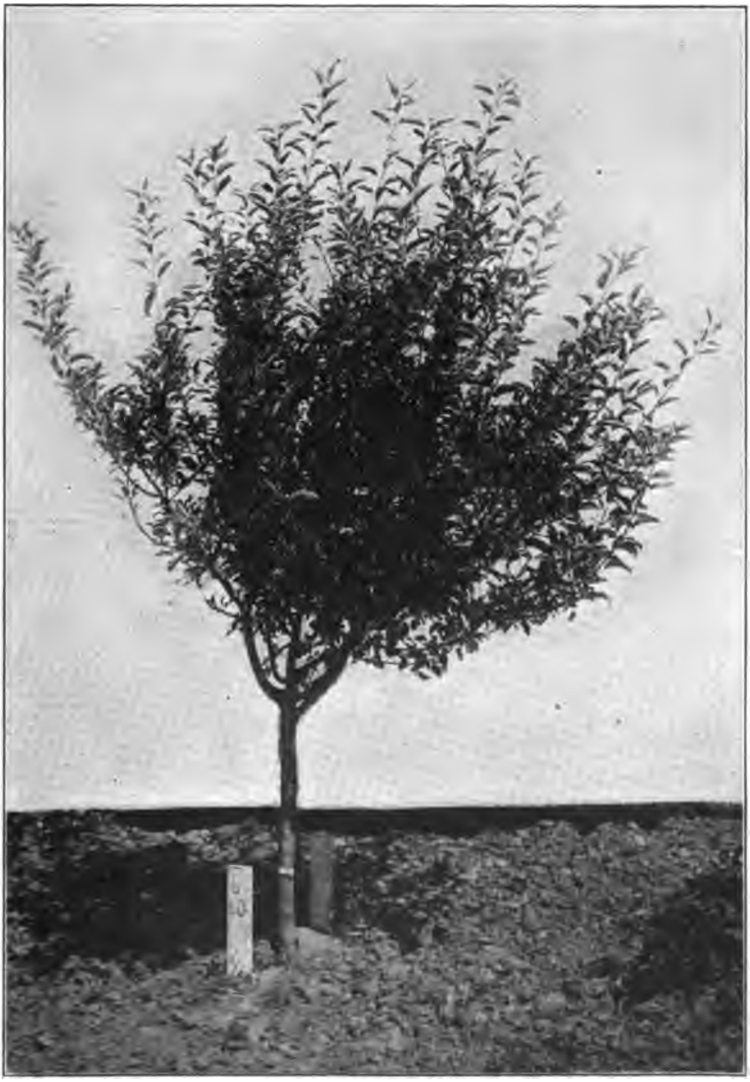

FIG. 38.—NO. 3191: GRIMES FROM BUD FROM DISTAL END OF SHOOT
HEIGHT, OCTOBER 13, 1915, 9 FEET, 6 INCHES

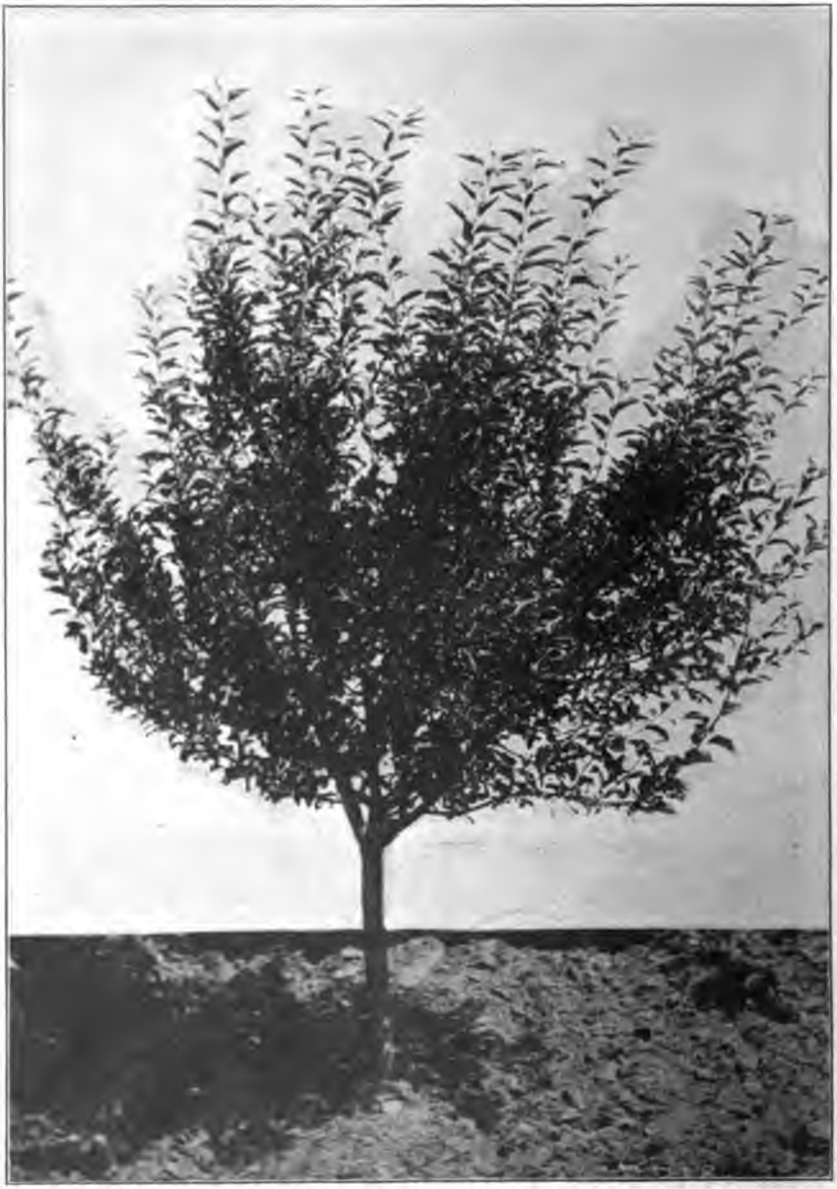

FIG. 39.—NO. 3177: GRIMES FROM BUD FROM MIDDLE OF SHOOT
HEIGHT, OCTOBER 13, 1915, 10 FEET, 3 INCHES

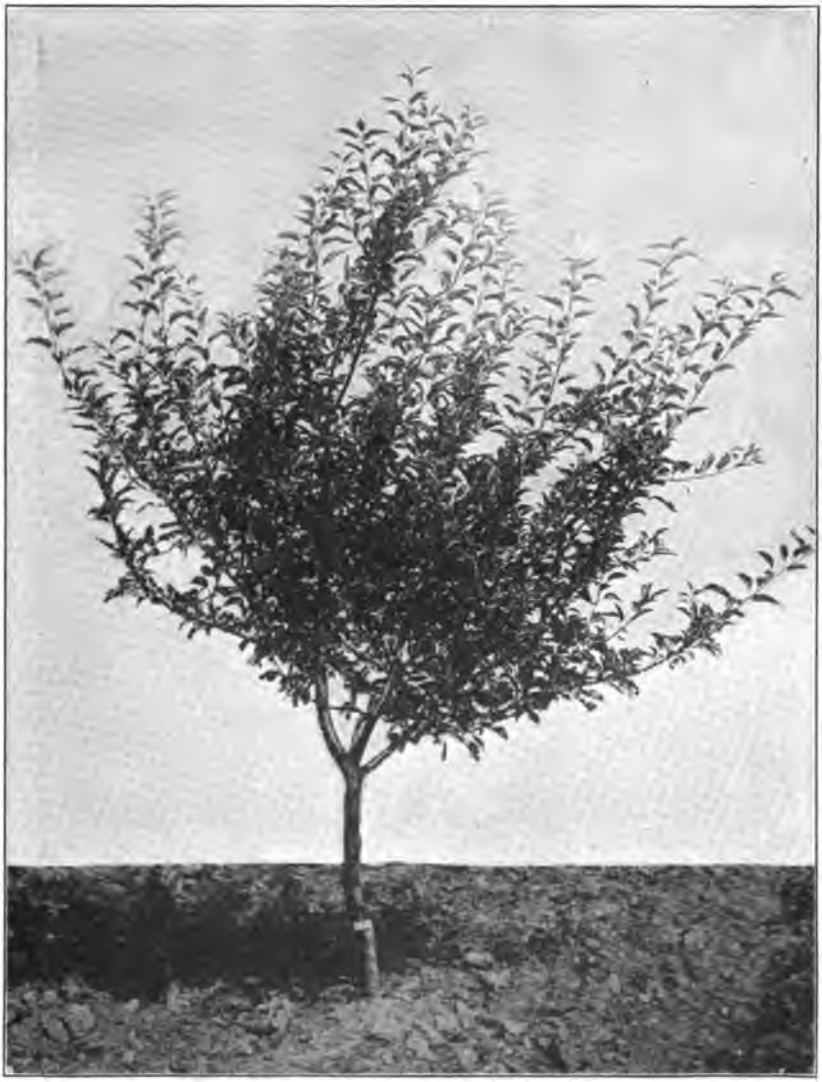

FIG. 40.—NO. 3185: GRIMES FROM BUD NEAR BASE OF SHOOT
HEIGHT, OCTOBER 13, 1915, 9 FEET, 6 INCHES

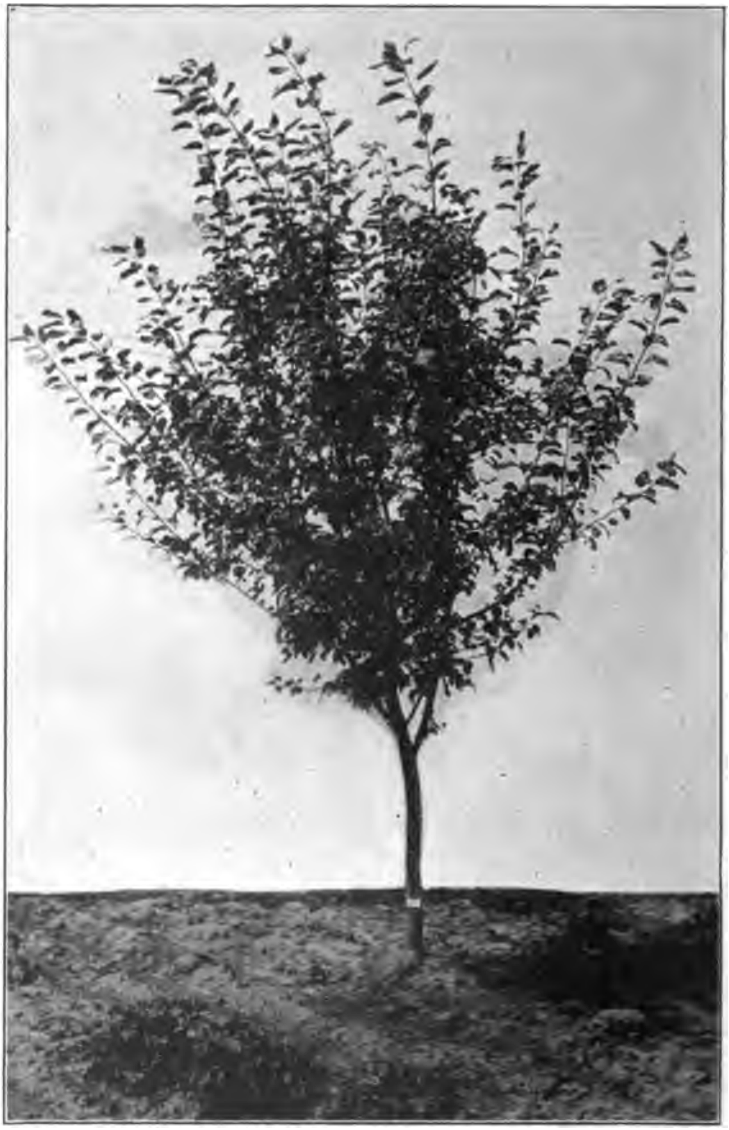

FIG. 41.—NO. 3083: OLDENBURG FROM TERMINAL BUD
HEIGHT, OCTOBER 13, 1915, 10 FEET, 9 INCHES

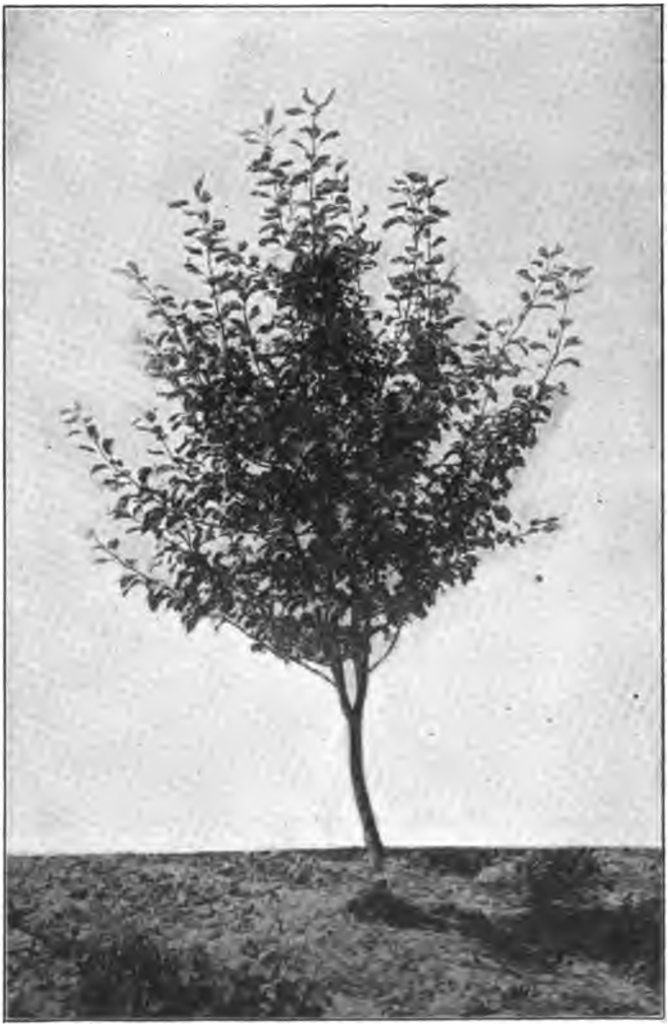

FIG. 42.—NO. 3106: OLDENBURG FROM BUD NEAR BASE OF SHOOT HEIGHT, OCTOBER 13, 1915, 9 FEET, 8 INCHES

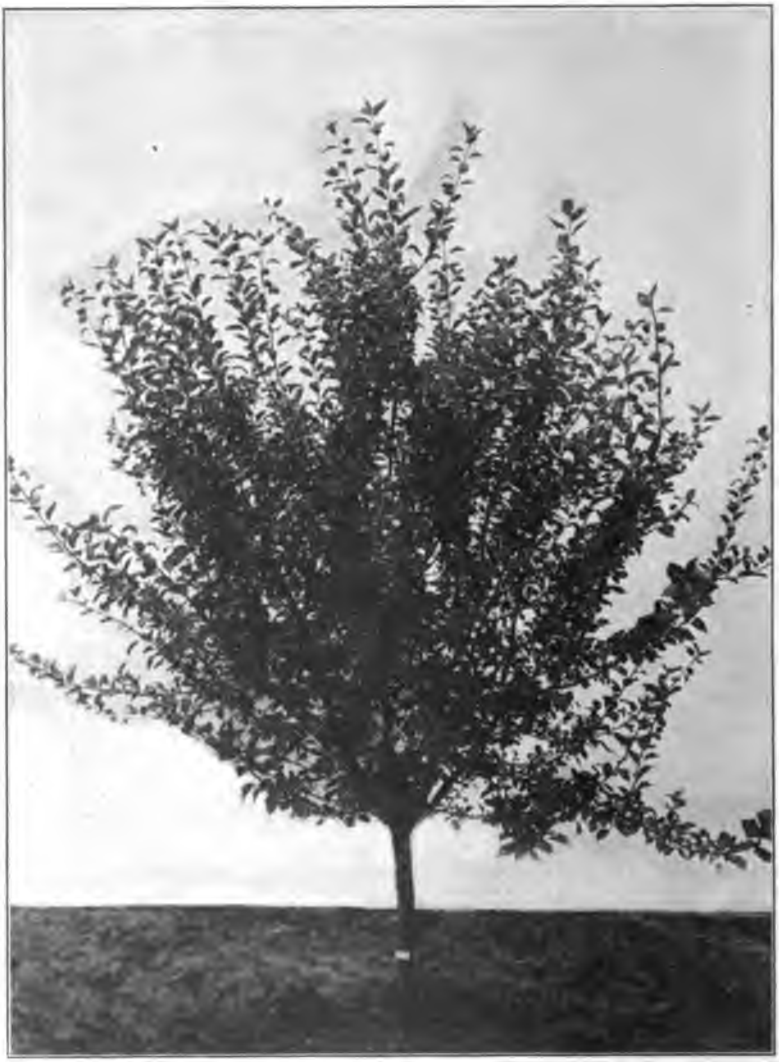

FIG. 43.—NO. 3079: WINESAP FROM BUD AT DISTAL END OF SHOOT
HEIGHT, OCTOBER 13, 1915, 11 FEET

When the results thus far obtained in this test of buds for purposes of propagation are platted, a striking uniformity in the growth curves is shown. The lines are so nearly coincident and indicate such slight departures from absolute uniformity that there remains no basis for any assumed differences in value of the buds tested. Results are negative. As large and as well-formed trees were grown from small buds as from large. Central terminal buds exhibited no advantages over extreme lateral buds, or over buds from interior branches, or even over buds from water sprouts, and the same results prevailed with reference to location on the shoot. Buds from near the base, from central, and from terminal locations gave equally good trees. These conclusions are based upon comparisons between the different lots of trees from buds from the different locations, but they should not convey the idea that there was perfect uniformity in the trees. Averages for the lots show uniformity, but within the groups of trees from buds from the same locations or from buds of uniform size, either large or small, there were often striking individual differences. For example, in comparing six trees of Grimes propagated from large buds, and eight years old, with six trees of the same age propagated from the smallest buds to be found on the tree, the average growth of the trees from large buds was found to be almost identical with the average of those from small buds, but the range of variation among the individuals of either group was considerable. Of the six trees from large buds the largest exceeded the smallest by 2 feet in height, 2 feet in spread, and ½ inch in trunk diameter. Of the six trees from small buds, the largest exceeded the smallest by 2 feet 8 inches in height, 2 feet in spread, and ⅞ inch in trunk diameter. These individual differences, sometimes greater, sometimes less, were common to all groups; they show the necessity of considerable numbers in order to make right comparisons between group averages.

Changes in the relative positions of individuals within a group when contrasted as to growth increments were quite common. Of two trees one might exceed the other in growth the first year, fall below it in the second, regain its advance position in the third year, again lose it, and again regain it, and so on for several years. The annual growth of two Winesap trees, which may be distinguished as A and B, illustrate this variation. Both were grafted on the same day in 1908; the buds chosen for the two trees were similarly situated near the bases of shoots; and the stocks upon which the scions were grafted were, to all appearances, similar. During the season of 1908, A made 33 percent more growth than B. In 1909, B exceeded A in total growth by 38 percent. In 1910, when the leaders only were measured, the length produced by B was two and one-half times that produced by A. In 1911, when measurements of total height were recorded, A exceeded B by 38 percent; in the next year, it maintained the lead by about 14

TABLE 21.—OLDENBURG: SHOWING GROWTH OF TREES FROM LARGE BUDS AND FROM SMALL BUDS

Bud class	Serial number	The bud			Total growth (inches)		Length of leader	Total height (inches)				
		Location	Length (mm.)	Breadth (mm.)	1908	1909	1910	1911	1912	1913	1914	1915
Large	1021	Terminal	6.25	4.25	15	26	9	34	34	34	39	62
Small	1033	Lateral	2.00	2.00	8	21	12	34	36	48	59	88
Large	1023	Terminal	5.00	4.50	14	20	9	40	44	60	69	94
Small	1034	Lateral	1.50	2.00	9	27	14	47	52	65	68	92
Large	1027	Terminal	6.00	4.25	17	25	13	52	47	78	83	104
Small	1038	Lateral	1.25	1.50	18	29	12	56	64	78	96	119
Large	1026	Terminal	6.25	5.00	13	34	12	48	56	72	80	101
Small	1031	Lateral	2.00	2.25	7	8	18	46	54	66	78	100
Large	1028	Terminal	6.00	3.75	18	24	14	56	64	73	81	99
Small	1035	Lateral	1.25	1.50	10	28	15	55	59	86	106	127

percent, but in 1913, B made the greater growth, exceeding A by 21 percent. In the two remaining years for which there is record, B continued to lead, exceeding A in 1914 by 18 percent, and in 1915 by 21 percent. Whether A will again lead, or remain in second place, is impossible to predict, but from many observations of these individual differences in growth it appears that, in general, differences become less with increase in age, provided the trees remain healthy. When two apparently healthy trees fluctuate in growth, as in the example cited, it is usually not possible to assign definite causes. Visible parts of the trees appear normal, but agencies that may operate to accelerate or retard root functions are hidden and cannot easily be discovered. The fluctuations in rate of growth here considered were apparent in all groups; hence their occurrence was entirely independent of the size of the initial buds from which the trees were grown or of the situation on tree or shoot from which the original buds were taken.

Growth of Selected Oldenburg Trees.—As a further exhibit of the relation between size of the chosen bud and subsequent growth, the measurements of ten Oldenburg trees, eight years old, may be given. Five of the trees were grown from buds selected as large and five from buds selected as small. Original bud measurements and growth records up to and including 1915 are given in Table 21. For convenience in comparing, the trees are arranged in pairs, a tree from a large bud associated with one from a small bud.

Four of the large buds were terminal, one was a lateral from just below an undeveloped terminal; two of the shoots from which buds were taken were top terminal, and three were short laterals from near the apex of the shoot of the preceding year. The small buds were all lateral from shoots from short interior branches. All the buds were selected to represent extremes in size; that they did this seems evident from the individual measurements. The large buds were all more than three times and in two cases nearly five times the length of the small; in all cases they were more than twice the breadth of the small buds. It may also be noted, altho not shown in the table, that scions carrying the large buds were in all cases larger than those carrying the small buds. Large buds, therefore, had not only the advantage that is supposed to belong to great size, but the additional advantage of the presumably larger store of reserve plant food to be found in the larger scions.

But larger size of bud and more robust scions appear to have had no influence upon subsequent growth other than is shown by the fact that, in the first season, four of the five pairs showed greater growth from the large buds. The remaining pair, in which the growth from the small bud slightly exceeded that from the large bud, chanced to be the one showing the greatest difference between the buds paired; the large bud was 4.8 times as long and 2.83 times as broad as the small bud. In two of the four pairs in which trees from large buds showed greater growth in the first year, the trees from small buds in the second year exceeded those from large buds, and in the other two pairs the advantage gained in the first year was maintained. For the third year the trees from small buds exceeded those from large buds in these four pairs. In the following five years there were fluctuations, and for the last year, 1915, the advantage in growth remained with trees from small buds in three of the pairs and with those from large buds in the other two pairs. The same irregularities in growth shown by Oldenburg appeared in other varieties and in other series of the test of size of buds. Nowhere was there any evidence tending to support the contention that large buds possess advantages over small buds for purposes of propagation.

COMPARATIVE VALUE OF ROBUST AND SLENDER SCIONS

The possible advantage accruing to buds borne on robust scions, because of the presumably greater supply of reserve nutrients than is to be found in slender scions, referred to above, may be studied by comparing a random selection of scions on the basis of scion diameters as shown by diameters of distal internodes. Ten scions were selected in which these diameters ranged from 4.5 to 7 mm., with an average of 5.15 mm., and for which the average length was 6.4 inches. These were all from top terminal shoots and were equally divided between Ben Davis and Oldenburg. Ten other scions selected had distal internode diameters of from 1.75 to 2 mm., with an average of 1.97 mm., and an average length of 5.77 inches. Of these scions seven were from shoots from short interior branches, two were from extreme lateral shoots, and one was from a water sprout. Four were from Grimes, three from Winesap, and three from Oldenburg.

To facilitate a comparison of records, the averages for each season are brought together in Table 22.

TABLE 22.—COMPARISON OF GROWTH OF TREES FROM ROBUST AND FROM SLENDER SCIONS
(Average in inches)

	No. of scions	Diam. of distal internode	Length of scion	Total growth		Growth of leader	Total height				
				1908	1909	1910	1911	1912	1913	1914	1915
Robust scions..	10	0.206	6.40	17.5	20.3	12.2	41.2	49.4	63.4	78.8	101.9
Slender scions..	10	0.079	5.77	16.7	15.4	10.7	39.8	50.7	64.1	81.8	110.9

This record shows that the initial growth from buds on robust scions was slightly greater than that from buds on slender scions and that the relative positions of the two groups remained the same to the end of the fourth season. In the fifth season the positions were reversed. The trees from buds on slender scions exceeded the others in height and continued this advantage thru 1915, or to the end of the record. However, neither in the first years, in which trees from robust scions had the advantage, nor in the last years, in which trees from slender scions made the greater growth, were differences such as to indicate marked superiority of one group over the other in growth.

While the differences in growth averages for the groups were insignificant, the fluctuations in growth of individuals within each group were decided, often extreme, and worthy of note. Arranging the trees from scions of large diameter according to the magnitude of growth in 1908, with No. 1 representing maximum growth and No. 10 the minimum, the top terminal scion of Ben Davis numbered 2009 occupied the position of No. 1. In 1909 it dropped to tenth place, having the minimum growth. In 1910 it rose to fifth place and in 1911 regained the position as No. 1, and this it held thru 1915. Another top terminal scion of Ben Davis, No. 2005, occupied second place in the list of 1908. In 1909 it dropped to fifth place and in 1910 to the bottom of the list. In 1911 it ascended to fifth place, then dropped to seventh, and still farther to ninth place in 1913; it rose to eighth place in 1914, then dropped to ninth in 1915. Third place in 1908 was occupied by No. 2004, another top terminal scion of Ben Davis; this fell to ninth place in 1909, rose to second place in 1910, then occupied fourth place for two seasons, had sixth place in 1913, dropped to tenth place in 1914, and remained in this position in 1915. The eighth place in 1908 was filled by the top terminal scion of Oldenburg numbered 2104. This rose to first place in 1909 and held it thru 1910. In 1911 it dropped to sixth place, occupied the eighth place in 1912 and 1913, rose to seventh in 1914, and remained in that position in 1915. Another similar scion, No. 2110, was in ninth place in 1908, second in 1909, third in 1910, eighth in 1911, tenth in 1912 and 1913, ninth in 1914, and eighth in 1915. At the bottom of the list in 1908 was No. 2103, also a top terminal Oldenburg scion. This rose to eighth place in 1909, and to first in 1910; then it dropped to sixth, remaining there two seasons, after which it rose thru fourth place in 1913 to second place in 1914 and 1915. Remaining numbers of the group fluctuated in like manner. Not one maintained an even course or exhibited any approach to uniformity in the increments of successive seasons. In the companion group of trees grown from attenuated scions, fluctuations in growth were shown by each individual just as extreme and irregular as those given as illustrations from the group of trees from scions of large diameter.

Summarizing the direction of movement of growth magnitudes after the first year (1908), it appears that for the ten trees from large scions, three made less growth in 1909, four increased in growth for that year, while the remaining three made the same growth in 1909 as in 1908 and then began fluctuating, one moving to less and two to greater growth. For the trees from attenuated scions six made less growth in 1909 than in 1908, three increased in growth for that year, while one made growth in 1909 equal to that of 1908 and after that fluctuated up and down within comparatively narrow limits, going from fourth place in the first two years to second place in the third year, fourth in the fourth year, third in the fifth year, fourth in the sixth year, and fifth in the last two years.

Now, the only fact that may be regarded as indicating superiority on the part of scions of large diameter, is that trees from such scions showed slightly greater averages of growth in the first years than did trees from the slender scions. Differences in the averages, however, were very small, and when it is considered that some individuals from slender scions in the first year showed equal growth with others from stout scions and in some cases even exceeded them, that in all seasons following the first, all trees fluctuated in amount of growth in a remarkable manner, and further, that in the last four years the differences in average growth transferred the apparent advantage to trees from slender scions, it appears that there is no tangible basis upon which to establish the idea that scions of large diameter, by virtue of size and presumably larger store of available nutrients, are superior to scions of small diameter for purposes of propagation. Each tree appeared to pursue its own course independently of others of its class; each added a yearly increment the magnitude of which was greater or less according as its surroundings were favorable or unfavorable to growth.

EFFECT OF VIGOR OF STOCK ON GROWTH

Aside from any influence upon growth that may be inherent in a particular bud or scion, there is the influence of the stock upon which the scion is grafted. All scions used in this test of buds were grafted, by the veneer method, upon crown pieces of ordinary apple seedlings as stocks. Any lot of seedlings exhibits wide variations in vigor and habit of growth; so these stocks, altho graded to eliminate weak individuals, still showed wide differences. Some were supplied with abundant roots and correspondingly large stems; others had few roots and slender stems. Vigor of stocks as measured in root production and stem growth existed in all degrees and each individual stock reflected its habit in some degree on the scion grafted upon it.

INFLUENCE OF CARE IN GRAFTING

Degree of perfection in the mechanical operations of grafting may also exercise an important influence upon growth of the scion. Among several hundred veneer grafts, even when made with extreme care, differences may be found in degree of perfection of contact between stock and scion. Slight convexities or concavities in the surfaces brought together prevent the complete and continuous contact of cambium essential to that prompt and efficient union which has an undoubted influence in advancing development from scion buds. Care of grafts during the period between making and planting in nursery, particularly with reference to temperature and uniformity in the supply of moisture, has an influence on subsequent growth and so also have care in planting, character of soil, and all those atmospheric conditions which singly or collectively operate to advance or retard plant growth.

VARIETAL AND INDIVIDUAL DIFFERENCES

Studies of the differences in annual increments and general behavior in growth of the trees grown from selected buds support and emphasize the fact of distinct individuality. In general habit the trees follow the parent varieties: Yellow Transparent, Whitney, and Oldenburg are upright, Grimes and Rome tend to rounded, symmetrical forms, while Ben Davis, Winesap, and Jonathan exhibit the usual irregularity in branch growth, tending to spreading and to more or less unsymmetrical shapes. But within any varietal group no two trees are alike. Often casual examination of a group gives the impression of great similarity, but close observation and measurements invariably bring out differences and show that the trees have reached their present state of development by very unequal increments.

Some extreme cases occurred in which individuals showed differences so conspicuous as to be readily noticed even by casual observers, as for example, two Ben Davis trees of exactly the same age, both from selected large buds from the same tree, the trees grown side by side in nursery and for the five years ending with 1915 fifteen feet apart in orchard. Both appeared healthy, but one was 54 percent taller than the other, had 87.5 percent more spread, and 100 percent greater trunk diameter. There were several other cases of equally great individual differences, but in general differences between individuals, altho appreciable, were much less. In most cases it is no more possible to assign specific causes for extreme individual differences than it is to assign them for the minor differences. In the example just given, the trees thruout life had been grown in such close proximity and so nearly under the same conditions that moisture, temperature, and other atmospheric conditions could not be considered as causes of the differences; for the same reason it appears improbable that soil conditions were in any way responsible for the wide differences observed in the other trees. Causes for the differences in growth, then, must lie with the individual plants, either in inherent qualities that belong to the stocks or to the scions, or to both, or to differences in the mechanical operation of grafting. The influence of these things is indeterminable and the causes of the differences remain unknown.

DISCUSSION OF RESULTS

In these tests many comparisons have been made between individuals of different groups and between entire groups, but no acceptable evidence has been found that growth of trees is in any way dependent upon size of scion, size of individual bud, location of bud upon the tree, or location of bud upon the shoot. No other conclusion is possible from the records than this: that all buds from healthy shoots are of equal value for purposes of propagation, at least so far as growth of trees is concerned.

GROWING SEEDLINGS FROM SEEDS OF FRUITS FROM TREES CHOSEN AS POSSESSING SPECIAL MERIT

This project was begun in 1908 and was considerably extended in 1909. The initial planting in the spring of 1909 was, in large part, a failure from various causes, so that few trees of that group survived and details of the group need not be given here further than to record something of the history of the remaining trees. Better success attended the planting made in the spring of 1910, of the seeds secured in the fall in 1909; this lot in 1915 was represented by more than three thousand living trees. Results under this project are not to be attained until the seedlings are established in fruit production; the little that need be recorded at this time concerns growth only.

SEEDLINGS FROM FRUITS OF 1908

In September, 1908, the Station received Grimes apples from the orchard of Perrine Brothers at Centralia. The fruits, 545 in number, all came from one tree that had an established reputation for productiveness. They were separated into two grades on the basis of size. All fruits having transverse diameters of 65 mm. or more were included in the group designated as "large"; those having transverse diameters of 64 mm. or less fell into the group designated as "small." Average weights and measurements of the two groups were as follows:

	Large	Small
Number of apples	293.00	252.00
Average weight of apples (grams)	130.70	106.31
Average longitudinal diameter (mm.)	57.00	57.25
Average transverse diameter (mm.)	67.00	62.00
Total apparently good seeds	2 079.00	1 417.00
Average seeds to the fruit	7.09	5.62

Among the large apples one had six cells; all others had the normal number of five. The seeds were stratified in sand in boxes and buried in earth for the winter. In the spring of 1909 there was unavoidable delay in preparation of ground for reception of the seeds, and when they were taken up and separated from the sand, germination had already begun. Some, presumably the seeds possessing greatest vitality, had progressed so far in germination that they did not survive shifting to nursery; thus a serious loss was incurred at the beginning. Of the seedlings that started growth, many were weak and a large proportion of these did not survive the first season.

The young trees were grown in nursery until they were four years old because no land was available upon which to plant at orchard distances. The number living at planting time in 1911 was 123; when finally planted 15 by 15 feet in orchard, on May 3, 1913, there remained 112 trees. Fourteen trees died later, so that at the end of 1915 there were living 98 trees seven years old.

All the trees were slow in starting growth after being planted in orchard and made but feeble growth that season. There was some improvement the next year and still further improvement in 1915, but the trees still had a stunted appearance which seemed likely to linger for some time if not permanently. The average height was a little less than six feet with an average spread of four and one-half feet. The last rating as to grade divided the trees as follows: good, 20 percent; fair, 58 percent; poor, 22 percent.

At about the same time that the Grimes apples were received, 452 Jonathan apples, taken from one of the most productive trees in the orchard of Mr. J. C. B. Heaton of New Burnside, Johnson county, were also received. These apples were graded into two size-groups on the same basis used in the division of the Grimes apples. The average weights and measurements were as below:

	Large	Small
Number of apples	374.00	78.00
Average weight of apples (grams)	141.46	93.83
Average longitudinal diameter (mm.)	60.31	52.26
Average transverse diameter (mm.)	70.91	60.59
Total apparently good seeds	2 157.00	423.00
Average seeds to the fruit	5.77	5.42

The Jonathan seeds were treated in exactly the same manner as the Grimes, and the seedlings of the two varieties were grown in contiguous rows each year. The Jonathan losses occurring were about equal to those sustained by Grimes; the number of trees remaining was small. In 1910 there were 78; in 1911 this number had fallen to 61, and this was the number planted in orchard 15 by 15 feet on May 3, 1913. Nine weak trees died later, leaving but 52 to represent this variety group. These trees had the same stunted appearance characterizing the Grimes seedlings; they had an average height of five and one-half feet and an average spread of five feet. Rated as to quality, at the same time the Grimes were rated, they classified as good, 27 percent; fair, 56 percent; poor, 17 percent.

The division of the apples of these two varieties into size-groups, at the time the seeds were collected, was made with the intention of testing the relative vigor of seedlings from seeds of large fruits as compared with those from seeds of small fruits. At the same time record was made of the number and distribution in cells of the seeds of each apple in an effort to determine whether or not there is a definite relation between seed production and size of fruit. The seedlings of these 1908 groups, however, were so few in number that the division between those from large fruits and those from small was abandoned, and further records, to be maintained until the seedlings are established in fruit production, consider them only as variety groups. The seed-production record was combined with other like records since obtained, and the whole is treated in a separate publication (Bulletin 203).

SEEDLINGS FROM FRUITS OF 1909

Seedlings from seeds collected in 1909, numbered, in 1915, above three thousand and represented six varieties. Such results as the project may yield when the fruiting characteristics have been determined will be derived mainly from these groups, and it therefore seems best to record the history of the trees in some detail.

All apples used in 1909 were supplied by Mr. J. C. B. Heaton from his orchards at New Burnside in Johnson county. They were barreled and shipped to the Station late in October. When received they were at once placed in storage, where they remained until the work of weighing and measuring them and extracting the seeds could be undertaken. Six varieties were represented, each by apples from a single tree that had been selected because of exceptional fruiting qualities.

Removal of seeds was begun November 9 and continued intermittently until finished November 29. The fruits of each variety were separated into two size-groups. The division point between large and small apples was fixed at 65 mm. as the minimum transverse diameter for large apples of Arkansas Black, Ben Davis, and Minkler, and at 58 mm. as the minimum transverse diameter for large apples of Rhenish May, Winesap, and Smith Cider. The groups of large fruits thus very closely correspond with the No. 1 grade for the classes to which the varieties belong. Each fruit was weighed, calipered for longitudinal and transverse diameters, then cut transversely for determination of the number and distribution of the seeds. As each lot was completed the seeds were sorted for the removal of those which had been accidentally injured by the knife in opening the fruit, or which had been partially eaten by codling-moth larvæ, or otherwise subjected to apparent injury. This process reduced the total of seeds by about 11 percent and left only those that, so far as could be judged by appearance, were capable of germination. Each lot of seeds was then stratified in sand in bulb pans and buried in earth.

Comparison of size-groups is not very satisfactory because of the wide differences in numbers of apples. In the aggregate of all varieties the large fruits were 2.8 times as many as the small and contained 3.22 times as many seeds. With each variety the averages of seeds to the fruit were larger for large fruits than for small. Bringing the groups of large apples together, Rhenish May led in number of seeds to the fruit with an average of 11.76; Minkler was the least productive, as shown by the average of 4.22 seeds. Assembling the groups of small apples, Winesap had the highest average, 8.91 seeds to each fruit, and here also Minkler had the lowest, 2.91 seeds to each fruit. Discarding size-groups and considering the aggregate of fruits for each variety, Rhenish May showed greatest productiveness with an average of 10.83 seeds for each fruit. The other varieties ranked in descending order as follows: Winesap, Smith Cider, Arkansas Black, Ben Davis, and Minkler.

To avoid repetition of the experience of the preceding year, when a considerable portion of the buried seeds germinated before it was possible to plant them, all the seed pans were taken up in February and placed in cold storage at a temperature of 31°F. On March 28, 1910, the seeds were separated from the sand and planted in nursery rows; they were then in excellent condition. It was the intention to determine the percentage of germination in each lot of seeds, but the demands of other projects were such that it was found impossible to do this, hence it is only known that germination was abundant.

During the first season the seedlings made that same slow, weak growth that appears to be characteristic of all apple seedlings grown on the black soil of this locality. About midsummer, at the time of hand-weeding the nursery, many weak seedlings were taken out to make more room for the better ones. In the fall of 1910 all were taken up for winter storage and again planted in nursery in the spring of 1911. This was repeated in the fall of 1911 and again in 1912. The aggregate of seedlings taken up for storage in the fall of 1911 was 5,648. In the fall of 1912 they numbered 5,315. In May, 1913, the seedlings, being then three years old, were permanently planted in orchard, 15 by 15 feet. The number thus planted was 4,988; of these, 4,568 were planted on the Station farm at the University and 420, 35 of each size-group of each variety, were sent to the Station farm at Olney in Richland county.

The losses indicated by the differences in the aggregates here given were mainly due to the death of seedlings that from the beginning had exhibited very low vitality. Many of these weak seedlings existed thru

TABLE 23.—MEASUREMENTS OF FRUITS AND ENUMERATION OF SEEDS FROM FRUITS OF 1909

Variety	Size-group	Number of apples	Average weight (grams)	Average diam. (mm.)		No. of seeds produced	No. of seeds discarded	Total seeds stratified	Aver. No. of seeds per fruit
				Longitudinal	Transverse				
Arkansas Black..........	Large	225	165.54	60.23	71.15	1 653	109	1 544	7.34
	Small	35	98.94	49.86	60.63	204	19	185	5.83
Ben Davis..............	Large	743	154.50	60.47	72.88	4 852	601	4 251	6.53
	Small	89	92.13	49.97	60.15	516	63	453	5.79
Minkler................	Large	748	174.63	57.55	73.87	3 163	1 289	1 874	4.22
	Small	24	106.31	47.38	61.05	70	1	69	2.91
Rhenish May...........	Large	2 159	105.74	50.63	62.73	25 403	2 557	22 846	11.76
	Small	469	73.42	44.02	54.15	3 081	352	2 729	6.57
Smith Cider............	Large	328	125.58	53.83	66.40	2 624	402	2 222	8.00
	Small	305	74.56	44.68	55.02	2 398	325	2 073	7.86
Winesap...............	Large	1 085	106.31	50.99	61.37	10 235	1 001	9 234	9.43
	Small	965	75.97	43.96	53.49	8 605	454	8 151	8.91
Total.............		7 175				62 804	7 173	55 631	

the second year in nursery and some thru the third year without making any appreciable growth. It is not to be understood that all weak seedlings had been eliminated at the time of planting in orchard. Some that were set out were but little more promising than many that had died, but were given their chance to overcome the weakness, if possible. Most of these weak trees did not improve; many died the first year in orchard, and others have since succumbed.

A few words are here necessary in explanation of the loss of a large number of trees during the first two seasons in orchard. The planting in the spring of 1913 was divided between two areas. In one forty-acre tract which was largely occupied by trees grown under other projects but which still had some unused space, there were planted 1,205 seedlings of three varieties as follows: Arkansas Black from seeds from large fruits, 108, from small fruits, 50; Ben Davis from large fruits, 392, from small fruits, 7; Smith Cider from large fruits, 328, from small fruits, 320. The trees were planted May 7 to 9. The soil here was well cultivated and in excellent condition for planting.

At the opening of spring in 1914, 159 trees, or 13 percent, had died. It was the small, weak trees that died, largely from inherent lack of vitality, but in part because of the extremely dry conditions that prevailed thruout the season. The second enumeration, made in the fall of 1915, two seasons after the first enumeration, showed an additional loss of only twenty-five trees, or a little more than 2 percent of the original planting. This small loss indicated that the weak trees had been eliminated. There remained at this time 1,021 trees: 352 classed as good, 429 as fair, and 240 as poor. These trees appeared to be established and most of them should reach maturity, produce fruit, and fulfil the purpose for which they were grown. They are by no means an even lot, but exhibit great diversity in growth habit and in vigor.

Seedlings of the remaining varieties, Rhenish May, Minkler, and Winesap, together with a few trees of Arkansas Black remaining after filling the area referred to above were planted May 15 to 22 on another forty-acre tract that at this time became available. This tract had been used for farm crops and had been neglected. It was not in satisfactory condition for the reception of trees, but the season was so far advanced that further delay was out of the question; the trees were planted as quickly as possible and much labor was expended in an effort to improve the unfortunate surroundings. No rain fell following planting and extreme drouth prevailed thruout the season. Three times at short intervals during July and August water was hauled in tanks and applied to the trees, but little benefit was derived from this treatment.

No enumeration of the trees was made until the spring of 1914, when the aggregate loss was ascertained to be 1,339 trees, or 40 percent of the number planted. The largest losses fell on Rhenish May, in which variety they amounted to 55 percent, while with Winesap the loss was only 21 percent. Of the 3,363 trees planted in the spring of 1913, there remained 2,024 in the spring of 1914. Some of these were shifted in the process of filling gaps and consolidating rows. From the time of enumeration in 1914 to the end of 1915 there was an additional loss of 175 trees; making the total loss 1,514 trees, or 45 percent of the number planted. Most trees made satisfactory growth in 1915, and, when the difficulties thru which they had lived are considered, the unfavorable conditions at time of planting and two summers of extreme drouth, it would seem that they had proved their resistant qualities and were safely on the way to full development and fruit production.

All the trees in this planting had a more or less stunted appearance; all were below normal size for trees six years of age. The growth made in 1915, however, gave promise that the stunted appearance would soon be overcome and that control of direction and amount of branch extension by pruning would, within a few years, bring the trees into satisfactory forms.

As the project stood at the close of the year 1915, six years from the planting of the seeds, there were in the two plantations on the University farm, 2,868 trees. Add to these the 365 trees which were living at the time of the last enumeration of the 420 planted at Olney, and the total number of surviving trees becomes 3,233, distributed as follows:

	NUMBER OF TREES IN 1915	From seed of large fruit	From seed of small fruit
Arkansas Black	University Farm	85	41
	Olney Farm	30	30
Ben Davis	University Farm	365	0
	Olney Farm	34	24
Minkler	University Farm	39	0
	Olney Farm	34	19
Rhenish May	University Farm	587	104
	Olney Farm	32	30
Smith Cider	University Farm	279	257
	Olney Farm	33	30
Winesap	University Farm	630	481
	Olney Farm	35	34

If the total number of living trees be compared with the total number of seeds planted, it appears that there was one tree for 17.2 seeds planted, or, expressed in percentage, 5.81 percent of the seeds planted persisted as living trees at the end of six years. The proportion of seeds surviving as trees was small and did not fairly represent the possibilities in apple-seedling production. No germination record was made, nor was any record kept of the seedlings destroyed in thinning during the first summer. The seedlings were first enumerated when two years old; at that time the number represented a little more than 10 percent of the seeds planted. The losses in the succeeding four years amounted to 43 percent, chiefly thru unfortunate conditions that were beyond control.

From the standpoint of future work on the project it is perhaps fortunate that the number of seedlings is no larger. To maintain accurate annual growth records, and particularly to diagram and describe the fruits of individuals as they are produced, is not a serious task when no more than one hundred trees are involved, but multiply these by thirty-two and the work is destined to tax the resources of the Department, especially in view of the fact that some thousands of trees grown under other projects promise demands for attention at the same time.

The six varieties here included showed considerable differences in numbers of seedlings living at the time of the first enumeration, when they were two years old, as contrasted with the numbers of seeds planted, and also in relative resistance as shown by a similar comparison of numbers of trees living in 1915. The groups of seedlings from seeds from large fruits will illustrate this. In 1911 the ratio of seedlings to seeds planted was 1 to 6 for Arkansas Black and Smith Cider, 1 to 10 for Ben Davis, 1 to 11 for Winesap, 1 to 12 for Rhenish May, and 1 to 25 for Minkler, while the ratio in 1915 was 1 to 8 for Smith Cider, 1 to 12 for Ben Davis, 1 to 15 for Winesap, 1 to 18 for Arkansas Black, 1 to 39 for Rhenish May, and 1 to 48 for Minkler; or, to indicate the losses during the four years by percentages, Ben Davis had the least, 17 percent, followed in order by Smith Cider with 23 percent, Winesap with 24 percent, Minkler with 48 percent, Arkansas Black with 68 percent, and Rhenish May with 69 percent.

Except for the two varieties Smith Cider and Winesap, comparisons between size-groups are unsatisfactory because of disparity of numbers. Two of the small size-groups are entirely eliminated, namely, Ben Davis and Minkler. The small size-group of Ben Davis was represented by only eighty-nine fruits, from which 455 seeds were planted. Only fifty-four seedlings were living at two years of age; only seven were planted in orchard, and these died that same year. The small size-group of Minkler had only twenty-four apples, which yielded 69 seeds; only fifteen weak seedlings survived to be planted in orchard in 1913 and these soon died. The small size-group of Arkansas Black had but thirty-five apples, from which 185 seeds were planted; most of the seeds germinated and seventy-seven trees lived to be planted in orchard in 1913. More seedlings in proportion to the number of seeds planted were produced by the seeds from small apples than by those from large apples. The ratio for the small size-group was 1 to 2.4, and for the large size-group, 1 to 14.29. Three years later the ratios between living trees and seeds planted were 1 to 4.51 for the small size-group and 1 to 18.16 for the large size-group. These ratios indicate a higher productiveness on the part of seeds from small fruits than is shown by seeds from large fruits. If, however, the percentage of trees lost in the three-year period between planting and the end of 1915 be examined, it is found that for the seedlings from seeds from small fruits the loss was more than twice as great as for those from seeds from large fruits. This indicates less resistance to adverse conditions and presumably a less degree of vitality in the seedlings from small fruits than is possessed by the seedlings from large fruits.

In Rhenish May the disparity in numbers between the size-groups was not so great as in Arkansas Black, Ben Davis, and Minkler, but the numbers of fruits, and hence of seeds, were much larger. Here the ratios between seedlings living in 1911 and seeds planted were 1 to 12.17 for seedlings from large fruits and 1 to 6.77 for those from small fruits. Four years later, in 1915, these ratios became 1 to 39 for seedlings from large fruits and 1 to 26.25 for those from small fruits, showing that the small fruits gave a larger number of seedlings in proportion to the number of seeds planted than did the large fruits, but, as with Arkansas Black, the percentage of loss between the first enumeration of seedlings and the end of the season of 1915, in this case four years, was greater for the seedlings from small fruits. With this variety the percentages of loss were much greater than with Arkansas Black, but the difference between loss percentages of the two size-groups was much less, 68.71 percent for seedlings from large fruits and 74.2 percent for those from small fruits. The difference is too small to indicate any clear superiority, in matters of resistance and vitality, of seedlings from fruits of large size over those from small fruits.

With Smith Cider and Winesap, parity of numbers of fruits and of seeds planted renders comparison of size-groups more satisfactory. These varieties, at the time of first enumeration in 1911, gave ratios between number of seedlings and number of seeds planted as follows: for Smith Cider 1 to 6 for seedlings from large fruits, 1 to 5 for seedlings from small fruits; for Winesap 1 to 11 for seedlings from large fruits and 1 to 10 for seedlings from small fruits. At the time of the last enumeration, four years later, the ratios were for Smith Cider 1 to 8 for each of the two groups; for Winesap 1 to 15 for progeny of large fruits, and 1 to 17 for progeny of small fruits. The ratios for Smith Cider showed, for 1911, a slight advantage in productiveness on the part of the small size-group, and equality for the two size-groups at the last count. For Winesap the advantage in productiveness was with the group from small fruits at the time of the first enumeration, but was transferred to the group from large fruits and was somewhat increased at the last enumeration. When percentages of loss for the four-year period between the enumerations considered are examined, the advantage is found to lie with the seedlings from large fruits in both varieties. These percentages are, for seedlings from large fruits, 23 for Smith Cider and 24 for Winesap; for seedlings from small fruits, 37 for Smith Cider and 43 for Winesap.

Bringing together the evidence bearing upon comparison of size-groups, it appears that relative productiveness as exhibited in ratios between numbers of trees living in 1915 and numbers of seeds planted was slightly better for seedlings from large fruits in the varieties having nearly equal numbers of fruits and seeds, and markedly to the advantage of seedlings from small fruits in the varieties in which the small size-groups were represented by too small numbers for satisfactory comparison.

Death of trees during the four-year period from the first enumeration, in the fall of 1911, to the close of the season of 1915, offers a better basis for comparison of the relative resistance to adverse conditions and the possession of sustaining vitality. In each of the four varieties having both size-groups represented, the losses were greater among seedlings from small fruits than among those from large fruits. In the two varieties Arkansas Black and Rhenish May, in which there was disparity of numbers in the groups, the differences between the loss percentages of the groups were small, but in Smith Cider and Winesap, where the numbers approximated equality, the differences were decided.

Combining the records here considered with many observations on the relative vitality of seedlings of the two size-groups, as indicated by the character and amount of growth, gives warrant for the conclusion that, in a general way, seedlings from seeds of large fruits are somewhat more resistant to adverse conditions and possess a higher degree of vitality than do seedlings from seeds of small fruits. Differences, however, were not perfectly constant and were often quite small, indicating that further definite records are needed before the question can be regarded as finally answered.

CONCLUSIONS

1. Summarized data giving comparisons between trees propagated from large buds and those propagated from small buds, together with the aggregate of impressions derived from careful inspections of trees of all groups, admit but one conclusion, namely, that

there are no differences, for purposes of propagation, between buds of large size and those of small size.

2. Growth curves of trees propagated from buds from different situations on the trees so closely approximate as to leave no basis for assuming that it makes any difference from what situation on the tree the buds are taken.

3. All buds from healthy shoots are of equal value for purposes of propagation, at least so far as growth of trees is concerned.

4. Fluctuations in growth of individuals within particular groups are decided, often extreme. In general, differences become less with increase in age, provided the trees remain healthy.

5. There is no tangible basis upon which to establish the assumption that robust scions are superior to scions of small diameter for purposes of propagation.

6. Studies of annual increments support and emphasize the fact of distinct individuality in growth of trees.

7. In general, seedlings from seeds of large fruits are somewhat more resistant to adverse conditions and possess a higher degree of vitality than do seedlings from seeds of small fruits.

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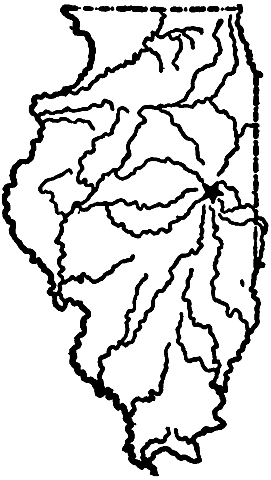
BULLETIN No. 212

LIMESTONE ACTION ON ACID SOILS

By ROBERT STEWART and F. A. WYATT



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LIMESTONE ACTION ON ACID SOILS

By ROBERT STEWART, Chief in Soil Fertility, and
F. A. WYATT, Assistant Chief in Soil Fertility

Lime, marl, or chalk has been applied to soils for many centuries. The early Romans certainly knew of the value of lime for sour soils, and they probably introduced its use into England at the time of the Roman conquest. There the beneficial effects of liming the soil have long been practiced. From the Rothamsted Experiment Station there is a definite record that as much as 100 tons of chalk per acre had been added a number of years before the beginning of the experimental work on that famous farm.

In America, the beneficial effect of the use of lime has been fully realized only within the last few years. Some of the older experiment stations, among them Pennsylvania, Maryland, and Rhode Island, were the first to demonstrate the benefit derived from liming the soil, and both Pennsylvania and Maryland also emphasized the feasibility of using ground limestone for this purpose. The work of the Illinois Experiment Station[1] has demonstrated the great value of ground limestone on acid soils. There are some questions, however, regarding the use of limestone upon which additional information is needed: viz.,

Can dolomitic limestone be used successfully on acid soils, and what is its value compared with high-calcium limestone?

What is the comparative value of the finely ground material and that more coarsely ground, which can be purchased more cheaply?

What is the durability of the various forms and kinds of lime when applied to soils in the field?

What effect does the application of limestone to the surface have upon the acidity of the subsurface and the subsoil?

What is the annual loss of limestone from the soil, and what are the factors which contribute to this loss?

A number of years ago some work was done at the Edgewood experiment field on some of these problems. The type of soil at Edgewood is gray silt loam on tight clay and belongs to the prairie land of the lower Illinoisan glaciation. This field, which has now been discontinued, consisted of three parts: west field, east field, and north field. The east field was divided into Series 300, which received ground limestone, and Series 400, which received freshly slaked lime.

Ferris,[2] who made a study of the effect of limestone on this field, shows dolomite to be twice as durable as high-calcium limestone; also that hydrated lime caused a loss per acre per annum of 192 pounds more nitrogen and 2,529 pounds more carbon from the upper twenty inches of soil than did ground limestone. Hopkins,[1] comparing Ferris' averages of eight treated plots and eight untreated, computes that 780 pounds of limestone are lost from the upper twenty inches of soil per acre per year.

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[1] Ill. Agr. Exp. Sta. Circs. 110 and 181 and Bul. 193.

[2] Ferris, Thesis: Studies in the Use of Lime and Limestone, 1912.

RESULTS FROM THE NEWTON EXPERIMENT FIELD

Investigations to determine the influence of forms, amounts, and degree of fineness of limestone were begun in 1912 on the University experiment field located about one mile west of Newton, in Jasper county. The soil is gray silt loam on tight clay and belongs to the prairie land of the lower Illinoisan glaciation. The land is practically level, having a fall of only a few feet in the entire length of the field. The outline of the investigations and the treatment of the various plots are shown in the accompanying plan.

In Series 100, 200, 300, and 400, which are devoted to grain and live-stock systems of farming, Plots 1, 5, and 10 are check plots, receiving no treatment. Plots 3, 4, 7, 8, and 9 receive dolomitic limestone (¼-inch mill-run, that is, from ¼ inch down to dust) at the rate of 3,000 pounds per acre, the application being made every third year for the legume. To Plots 2, 3, and 4 manure is applied for corn once during the rotation, and in proportion to the crops produced. Plots 6, 7, 8, and 9 receive organic matter in the form of the crop residues and cover crops grown upon these plots. Plots 4, 8, and 9 receive phosphorus in fine-ground, raw rock phosphate, while Plot 9 also receives potassium in kainit. Series 100, 200, and 300 are tile-drained, while Series 400 is not tiled. The rotation in these four series is: (1) corn, (2) soybeans (or cowpeas), and (3) wheat, with a legume cover crop (sweet clover) seeded in the wheat on Plots 6, 7, 8, and 9, which are devoted to the grain system. Series 400 always grows the same crop as Series 200, and also receives the same application of limestone applied at the same time.

The amounts and dates of the applications of limestone are recorded in Table 1.

TABLE 1.—LIMESTONE APPLIED ON SERIES 100, 200, 300, 400: NEWTON FIELD
(Pounds per acre)

Series	1912	1913	1914	1915	Total
100	1 000	3 000	.....	....	4 000
200	2 000	....	3 000	....	5 000
300	3 000	....	....	3 000	6 000
400	2 000	....	3 000	....	5 000

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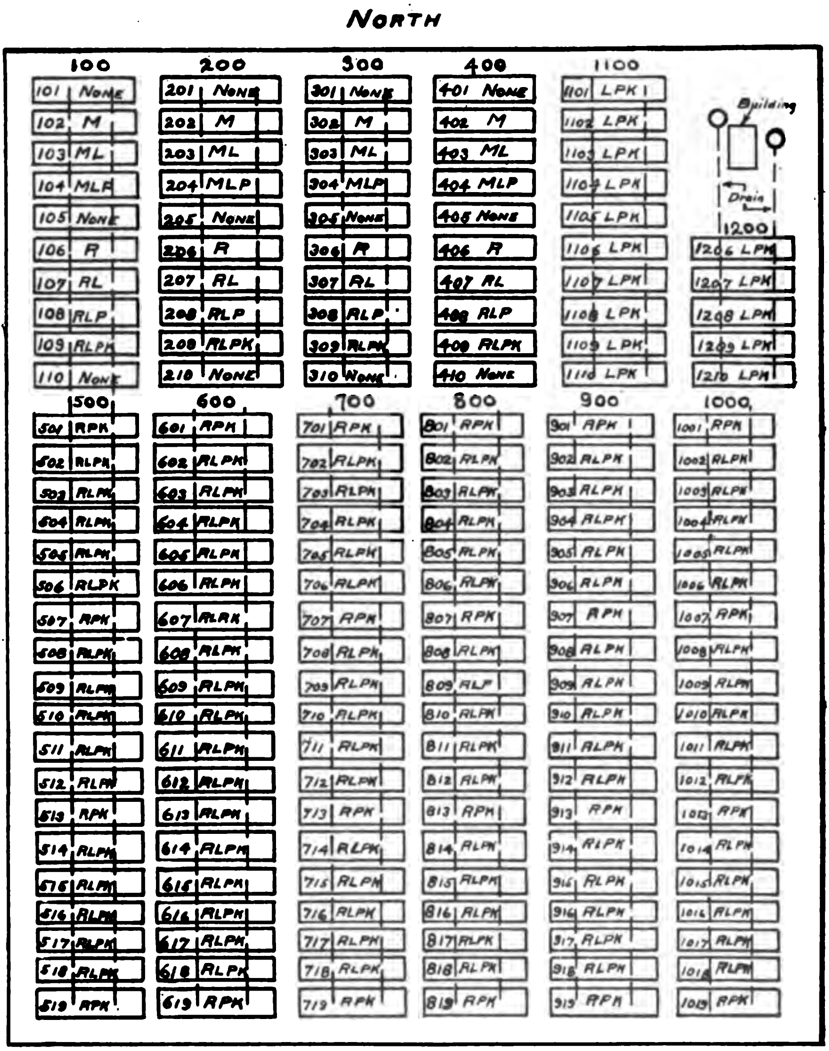
[1] Hopkins, Ill. Agr. Exp. Sta., Soil Report 3, page 8.



PLAN OF NEWTON EXPERIMENT FIELD

EFFECT OF LIMESTONE ON THE SURFACE SOIL
(Series 100 to 400)

In May, 1916, about three and one-half years after the application of limestone was begun, samples of soil were obtained from each plot for analysis for limestone and acidity. Samples were taken from the surface (0 to 6⅔ inches), the subsurface (6⅔ to 20 inches), and the subsoil (20 to 40 inches). Composite samples were obtained by taking twelve borings from each plot. The acidity was measured in terms of pure limestone (calcium carbonate) required to neutralize it; and the limestone present was also reported in terms of calcium carbonate, as measured by the carbon dioxid liberated by strong acid.

The effect of the application of limestone on the surface soil of these series may be seen from a study of the data recorded in Table 2. The limestone applied had not yet destroyed all the acidity in the surface soil, altho in all plots it had materially reduced the amount present and in most cases had destroyed almost all the acidity present. On the other hand, in all plots on which limestone had been applied a considerable amount was still present in the soil. Even in Series 100, where the latest application had been made in 1913 and where the total application had been only 4,000 pounds, the average amount of limestone remaining in the soil in 1916 was 881 pounds per acre; that is, two and one-half years after the latest application of limestone to this series, appreciable amounts of applied limestone could still be found in the surface soil of the limed plots, while an average of 563 pounds of acidity per acre had been destroyed and an average of 487 pounds of acidity still remained. Computations bringing out similar facts may be made for the other series. The amount of limestone which had been destroyed or lost, either by neutralizing acidity present or by being carried off in the drainage as soluble salts of calcium and magnesium, was considerable.

The amount of acidity found in the soil of the untreated plots varied from plot to plot; for example, from 918 pounds on Plot 101 to 1,808 pounds on Plot 102, so that too much importance should not be attached to the figures from individual plots.

TABLE 2.—EFFECT OF LIMESTONE ON SURFACE SOIL, SERIES 100 TO 400: NEWTON FIELD, 1916

Average pounds calcium carbonate in 2 million pounds of surface soil (one acre about 0 to 6⅔ inches deep)

Plot No.	Treatment	Limestone added		Soil acidity		Limestone	
		Degree of fineness	Amount, *lbs.*	Destroyed	Found	Amount found	Annual loss
Series 100							
101	0	......	....	....	918	....	....
102	M	......	....	....	1 808	....	....
103	ML	¼ inch down	4 000	215	948	404	966
104	MLP	¼ inch down	4 000	531	632	896	735
105	0	......	....	....	763	....	....
106	R	......	....	....	1 018	....	....
107	RL	¼ inch down	4 000	456	518	997	728
108	RLP	¼ inch down	4 000	852	122	979	619
109	RLPK	¼ inch down	4 000	760	214	1 131	602
110	0	......	....	....	1 140	....	....
Series 200							
201	0	......	....	....	2 120	....	....
202	M	......	....	....	2 368	....	....
203	ML	¼ inch down	5 000	1 951	330	1 556	426
204	MLP	¼ inch down	5 000	2 152	130	1 817	295
205	0	......	....	....	2 356	....	....
206	R	......	....	....	2 114	....	....
207	RL	¼ inch down	5 000	2 051	180	1 458	426
208	RLP	¼ inch down	5 000	2 089	142	1 888	291
209	RLPK	¼ inch down	5 000	2 181	50	1 808	289
210	0	......	....	....	2 224	....	....
Series 300							
301	0	......	....	....	2 552	....	....
302	M	......	....	....	2 304	....	....
303	ML	¼ inch down	6 000	2 132	142	2 450	404
304	MLP	¼ inch down	6 000	2 132	142	3 174	198
305	0	......	....	....	1 968	....	....
306	R	......	....	....	1 752	....	....
307	RL	¼ inch down	6 000	1 531	252	3 613	245
308	RLP	¼ inch down	6 000	1 691	92	3 827	137
309	RLPK	¼ inch down	6 000	1 560	222	3 017	406
310	0	......	....	....	1 628	....	....
Series 400							
401	0	......	....	....	964	....	....
402	M	......	....	....	598	....	....
403	ML	¼ inch down	5 000	707	142	1 122	906
404	MLP	¼ inch down	5 000	746	102	1 852	686
405	0	......	....	....	984	....	....
406	R	......	....	....	1 530	....	....
407	RL	¼ inch down	5 000	930	138	3 051	291
408	RLP	¼ inch down	5 000	927	141	3 265	231
409	RLPK	¼ inch down	5 000	684	384	965	958
410	0	......	....	....	690	....	....

TABLE 2.—*Concluded*

Plot No.	Treatment	Limestone added		Soil acidity		Limestone	
		Degree of fineness	Amount, *lbs.*	Destroyed	Found	Amount found	Annual loss
		Average of Results from All Four Series					
1	0..........	......	....	....	1 638	....	....
2	M..........	......	....	....	1 769	....	....
3	ML........	¼ inch down	5 000	1 251	390	1 382	675
4	MLP.......	¼ inch down	5 000	1 390	254	1 935	478
5	0..........	......	....	....	1 518	....	....
6	R..........	......	....	....	1 604	....	....
7	RL........	¼ inch down	5 000	1 242	272	2 279	422
8	RLP.......	¼ inch down	5 000	1 389	124	2 489	319
9	RLPK.....	¼ inch down	5 000	1 296	217	1 730	563
10	0..........	......	....	....	1 420	....	....

EFFECT OF DRAINAGE UPON LOSS OF LIMESTONE

(Series 100 to 400)

The data showing the effect of drainage on loss of limestone are summarized in Table 3.

Comparing the drained portion of the field with the undrained portion, there is found, as an average of all limestone-treated plots of Series 100, 200, and 300 (drained), 1,934 pounds per acre of limestone and 1,485 pounds of acidity destroyed and an annual loss from the surface soil of 435 pounds of limestone; whereas in Series 400 (undrained) there is found 2,051 pounds per acre of limestone present and 799 pounds of acidity destroyed, and an annual loss of 614 pounds of limestone. However, there is as great a difference between any two of the drained series as between the drained and the undrained series. Thus, Series 100 shows, as an average, 881 pounds per acre of limestone present, 563 pounds of acidity destroyed, and an annual loss of 730 pounds per acre, while Series 300 shows 3,216 pounds of limestone present, 1,809 pounds of acidity destroyed, and an annual loss of

TABLE 3.—EFFECT OF DRAINAGE UPON LOSS OF LIMESTONE, SERIES 100 TO 400: NEWTON FIELD, 1916

Average pounds calcium carbonate in 2 million pounds of surface soil (one acre about 0 to 6⅔ inches deep)

	Drained				Undrained	General average
Series..................	100	200	300	Average	400	
Limestone applied......	4 000	5 000	6 000	5 000	5 000	5 000
Limestone found........	881	1 705	3 216	1 934	2 051	1 964
Acidity destroyed	563	2 084	1 809	1 485	799	1 314
Total limestone accounted for..........	1 444	3 789	5 025	3 419	2 850	3 277
Annual loss from surface soil..................	730	345	278	435	614	491

278 pounds of limestone. Series 100 received but 4,000 pounds of limestone, while Series 300 received 6,000 pounds. Series 200 and 400 each received 5,000 pounds; but Series 200 shows an average of 1,705 pounds of limestone present, 2,084 pounds of acidity destroyed, and an annual loss of 345 pounds, compared with 2,051 pounds of limestone present and 799 of acidity destroyed, and an annual loss of 614 pounds of limestone for Series 400, which had not been drained.

From the above data it may be seen that the variations between the series are greater than the difference between the drained and the undrained land, and that no conclusion is yet justified as to the effect of drainage upon the loss of limestone from this type of soil.

INFLUENCE OF APPLICATIONS OF LIMESTONE TO SURFACE SOIL UPON ACIDITY IN THE SUBSURFACE AND SUBSOIL

(Series 100 to 400)

The data for limestone and acidity present in the subsurface of Series 100 to 400 are recorded in Table 4. There is some evidence that the limestone applied to the surface penetrated into the subsurface and destroyed some subsurface acidity (an average of 1,017 pounds per acre) during the time that had elapsed since the initial application, but the plot variations are so great as to give plus and minus quantities even in the serial averages, and this renders the final average less trustworthy. There is also evidence that the native limestone, often found in the subsoil, in some places extended upward into the subsurface.

The data for limestone and acidity present in the subsoil may be found in Table 5. The irregularity of the results, together with the

TABLE 4.—EFFECT OF LIMESTONE ON SUBSURFACE, SERIES 100 TO 400: NEWTON FIELD, 1916

Average pounds calcium carbonate in 4 million pounds of subsurface soil (one acre about 6⅔ to 20 inches deep)

Plot No.	Series....	100	200	300	400	100	200	300	400	Average
	Treatment	Limestone found				Acidity found				
1	0..........	..	..	..	..	4 944	9 348	7 388	6 888	7 142
2	M..........	..	..	..	..	6 100	6 892	6 808	8 400	7 050
3	ML........	..	..	380	94	8 624	5 876	6 624	9 980	7 776
4	MLP.......	..	514	524	..	6 464	5 876	4 604	6 688	5 908
5	0..........	..	..	2 356	..	2 292	6 488	2 708	7 012	4 625
6	R..........	..	..	..	..	980	6 404	5 724	6 092	4 800
7	RL........	346	..	490	926	736	5 712	3 644	2 832	3 231
8	RLP.......	..	686	662	410	204	5 652	3 140	904	2 475
9	RLPK.....	174	482	754	..	2 164	5 828	2 852	492	2 834
10	0..........	..	..	..	..	3 660	6 276	4 204	644	3 696
Average for limed plots....................						3 638	5 789	4 173	4 179	4 445
Average for unlimed plots..................						3 595	7 082	5 366	5 807	5 462
Acidity destroyed....................						(–43)	1 293	1 193	1 628	1 017

fact that limestone was found in most of the check plots, indicates clearly that the presence of limestone in this stratum was due entirely to its native occurrence and not at all to the applications made to the surface soil.

Table 5.—Effect of Limestone on Subsoil, Series 100 to 400:
Newton Field, 1916

Average pounds calcium carbonate in 6 million pounds of subsoil (one acre about 20 to 40 inches deep)

Series........		100	200	300	400	100	200	300	400
Plot No.	Treatment	Limestone found				Acidity found			
1	0........	...	468	816	...	23 868	38 424	32 454	17 058
2	M........	...	834	...	1 140	26 580	36 006	28 032	11 514
3	ML......	...	1 194	666	468	25 932	39 360	25 502	3 876
4	MLP....	984	576	714	5 550	8 682	28 254	22 866	156
5	0........	7 428	360	462	4 146	546	24 576	13 644	...
6	R........	26 652	...	462	3 210	246	18 756	13 722	174
7	RL......	26 418	1 398	3 876	17 052	...	26 094	978	...
8	RLP.....	7 782	...	5 820	26 754	...	25 302	216	...
9	RLPK...	2 862	234	5 412	30 216	156	29 682	552	...
10	0........	2 076	828	8 664	13 626	216	28 008	186	...

Comparative Value of High-Calcium and Dolomitic Limestone

(Series 500 to 1000)

From Series 500 to 1000 data were gathered from which to study the comparative effects of applications of high-calcium and dolomitic limestone, together with the effects of the various grades of fineness of limestone, including burnt lime. On these series the rotation is: (1) corn, (2) soybeans (or cowpeas), and (3) wheat, with the legume cover crop (sweet clover). These six series are arranged in three groups of two pairs each. The same crop is grown on the two series of each pair. Thus, in the year in which corn occurs on Series 500 and 600, soybeans are on Series 700 and 800 and wheat on Series 900 and 1000. In Series 500, 700, and 900, the limed plots receive high-calcium limestone or burnt lime, while in Series 600, 800, and 1000 they receive dolomitic limestone or dolomitic burnt lime. Plots 1, 7, 13, and 19 of each series receive no lime treatment. Plots 2 to 6 receive a light application equivalent to 500 pounds per acre per year of pure calcium carbonate, while Plots 8 to 12 receive a medium application of twice this amount, and Plots 14 to 18 receive a large application of four times this amount. In other words, the applications are made on the basis of the equivalent of 500, 1,000, and 2,000 pounds of pure calcium carbonate per acre per annum; three times these amounts being applied every third year. The amounts of limestone applied to these series, together with the dates of application, are recorded in Table 6. The degree of fineness of the limestone applied is given below:

Plots 2, 8, 14 receive ¼ inch down (mill-run)
" 3, 9, 15 " ¼ inch to 1/10 inch
" 4, 10, 16 " 1/10 inch down
" 5, 11, 17 " 1/60 inch down
" 6, 12, 18 " burnt lime

All plots in these series receive uniform applications of rock phosphate, kainit, and crop residues, including the cover crops plowed under.

TABLE 6.—LIMESTONE APPLIED ON SERIES 500 TO 1000: NEWTON FIELD
(Pounds per acre)

Series	Year				Total
	1912	1913	1914	1915	
		Light Application: Plots 2 to 6			
500	500	1 500	....	....	2 000
600	500	1 500	....	....	2 000
700	1 000	....	1 500	....	2 500
800	1 000	....	1 500	....	2 500
900	1 500	....	....	1 500	3 000
1000	1 500	....	....	1 500	3 000
		Medium Application: Plots 8 to 12			
500	1 000	3 000	....	....	4 000
600	1 000	3 000	....	....	4 000
700	2 000	....	3 000	....	5 000
800	2 000	....	3 000	....	5 000
900	3 000	....	....	3 000	6 000
1000	3 000	....	....	3 000	6 000
		Heavy Application: Plots 14 to 18			
500	2 000	6 000	....	....	8 000
600	2 000	6 000	....	....	8 000
700	4 000	....	6 000	....	10 000
800	4 000	....	6 000	....	10 000
900	6 000	....	....	6 000	12 000
1000	6 000	....	....	6 000	12 000

Samples of soil for analysis were taken in 1916. The data obtained are arranged in Table 7. As will be seen from this table, the plots receiving no lime (1, 7, 13, and 19) showed much variation in soil acidity; but, as an average, the original acidity seems to have been slightly higher in that part of the field where the heavier applications of limestone had been made, especially on Series 500 to 800.

In Table 8 the data appearing in Table 7 are summarized for convenience of study. These results were obtained by averaging data from all plots receiving equivalent applications, irrespective of the degree of fineness. Each serial number, then, is the average of the results from five separate plots. Thus, the general averages are based upon forty-five separate plots; and these results, therefore, are rea-

TABLE 7.—EFFECT OF FORM, AMOUNT, AND DEGREE OF FINENESS OF LIMESTONE UPON SURFACE SOIL: NEWTON FIELD, 1916
Average pounds calcium carbonate in 2 million pounds of surface soil (one acre about 0 to $6\frac{2}{3}$ inches deep)

Series			500	600	500	600	500	600	500	600
Lime applied			High calcium	Dolomitic	High calcium	Dolomitic	High calcium	Dolomitic	High ca'cium	Dolomitic
Plot No.	Degree of fineness	Amount, *lbs.*	Limestone found		Soil acidity found		Soil acidity destroyed		Annual loss of limestone	
1	No lime	....	....	....	1 118	1 250	....	....	....	....
2	1/4 inch down	2 000	112	493	408	438	759	758	322	214
3	1/4 to 1/10 inch	2 000	262	919	438	632	780	512	273	163
4	1/10 inch down	2 000	None	611	436	366	833	726	333	190
5	1/50 inch down	2 000	None	51	508	224	812	816	339	324
6	Burnt lime	2 000	24	19	598	548	773	440	343	440
7	No lime	....	....	....	1 422	934	....	....	....	....
8	1/4 inch down	4 000	958	1 511	762	530	806	478	639	574
9	1/4 to 1/10 inch	4 000	1 010	2 089	294	428	1 420	752	450	331
10	1/10 inch down	4 000	196	679	508	500	1 352	652	701	762
11	1/50 inch down	4 000	314	135	518	396	1 488	828	628	867
12	Burnt lime	4 000	78	303	936	142	1 216	1 154	773	726
13	No lime	....	....	....	2 298	1 368	....	....	....	....
14	1/4 inch down	8 000	2 464	2 385	174	212	2 125	1 362	974	1 215
15	1/4 to 1/10 inch	8 000	2 346	4 253	244	82	2 055	1 698	1 029	585
16	1/10 inch down	8 000	1 072	2 591	540	82	1 759	1 904	1 476	1 000
17	1/50 inch down	8 000	1 036	1 657	482	234	1 817	1 958	1 471	1 253
18	Burnt lime	8 000	882	645	172	162	2 127	2 236	1 426	1 462
19	No lime	....	....	....	2 300	2 602	....	....	....	....

TABLE 7.—*Continued*

Series			700	800	700	800	700	800	700	800
Lime applied			High calcium	Dolomitic	High calcium	Dolomitic	High calcium	Dolomitic	High calcium	Dolomitic
Plot No.	Degree of fineness	Amount, *lbs.*	Limestone found		Soil acidity found		Soil acidity destroyed		Annual loss of limestone	
1	No lime	....	....	....	478	568	....	....	....	....
2	¼ inch down	2 500	874	576	72	228	460	506	333	406
3	¼ to 1/10 inch	2 500	1 182	1 274	112	100	478	800	240	122
4	1/10 inch down	2 500	736	794	202	224	446	841	376	247
5	1/50 inch down	2 500	178	158	178	446	528	786	412	444
6	Burnt lime	2 500	634	None	192	708	572	688	370	517
7	No lime	....	....	....	820	1 562	....	....	....	....
8	¼ inch down	5 000	2 972	1 734	None	468	901	1 154	322	603
9	¼ to 1/10 inch	5 000	2 036	2 304	82	125	898	1 559	590	325
10	1/10 inch down	5 000	1 108	1 056	40	954	1 019	792	821	901
11	1/50 inch down	5 000	464	1 090	344	962	796	846	1 068	875
12	Burnt lime	5 000	656	240	102	828	1 114	1 042	923	1 062
13	No lime	....	....	....	1 298	1 930	....	....	....	....
14	¼ inch down	10 000	4 381	4 361	Alkaline	Alkaline	1 258	1 914	1 246	1 064
15	¼ to 1/10 inch	10 000	3 521	7 381	Alkaline	Alkaline	1 221	1 900	1 502	205
16	1/10 inch down	10 000	5 321	4 741	Alkaline	Alkaline	1 186	1 887	998	963
17	1/50 inch down	10 000	3 821	6 671	Alkaline	Alkaline	1 147	1 872	1 437	416
18	Burnt lime	10 000	1 827	2 048	Alkaline	Alkaline	1 111	1 858	2 017	1 741
19	No lime	....	....	....	1 074	1 844	....	....	....	....

TABLE 7.—*Concluded*

Series			900	1000	900	1000	900	1000	900	1000
Lime applied			High calcium	Dolomitic	High calcium	Dolomitic	High calcium	Dolomitic	High calcium	Dolomitic
Plot No.	Degree of fineness	Amount, *lbs.*	Limestone found		Soil acidity found		Soil acidity destroyed		Annual loss of limestone	
1	No lime	....	....	....	710	1 074	....	....	....	....
2	1/4 inch down	3 000	332	1 314	264	324	508	795	617	254
3	1/4 to 1/10 inch	3 000	1 518	1 752	182	670	654	494	236	215
4	1/10 inch down	3 000	568	1 078	244	458	656	751	507	334
5	1/50 inch down	3 000	448	796	670	670	294	584	645	463
6	Burnt lime	3 000	620	1 058	162	162	866	1 137	432	230
7	No lime	....	....	....	1 094	1 344	....	....	....	....
8	1/4 inch down	6 000	1 178	1 326	202	224	789	1 052	1 152	1 035
9	1/4 to 1/10 inch	6 000	3 040	2 226	142	264	748	944	632	808
10	1/10 inch down	6 000	906	2 204	60	142	729	1 008	1 247	796
11	1/50 inch down	6 000	566	1 388	446	142	242	930	1 483	1 052
12	Burnt lime	6 000	938	1 678	82	None	505	1 004	1 302	933
13	No lime	....	....	....	486	934	....	....	....	....
14	1/4 inch down	12 000	3 549	6 258	42	40	634	916	2 233	1 379
15	1/4 to 1/10 inch	12 000	4 983	6 176	None	60	866	916	1 757	1 402
16	1/10 inch down	12 000	2 823	4 802	None	40	1 056	956	2 320	1 782
17	1/50 inch down	12 000	4 195	3 894	102	None	1 144	1 016	1 903	2 025
18	Burnt lime	12 000	2 865	2 666	None	None	1 436	1 036	2 199	2 371
19	No lime	....	....	....	1 626	1 054	....	....	....	....

TABLE 8.—COMPARATIVE EFFECT OF HIGH-CALCIUM AND DOLOMITIC LIMESTONE (INCLUDING BURNT LIME), SERIES 500 TO 1000: NEWTON FIELD, 1916

Average pounds calcium carbonate in 2 million pounds of surface soil (about 0 to 6⅔ inches deep)

Series	500	600	700	800	900	1000	Average of all series			
Lime applied	High calcium	Dolomitic	High calcium	Dolomitic	High calcium	Dolomitic	High calcium	Dolomitic	High calcium	Dolomitic
	Limestone Found								Annual loss	
Light application	79	418	721	560	697	1 198	499	725	392	304
Medium application	511	943	1 449	1 285	1 325	1 764	1 095	1 330	849	777
Heavy application	1 560	2 306	3 774	5 040	3 683	4 759	3 005	4 035	1 599	1 258
Average annual loss									946	779
	Acidity Destroyed									
Light application	791	650	497	724	596	752	628	708	....	....
Medium application	1 256	773	946	1 079	605	988	936	947	....	....
Heavy application	1 977	1 832	1 185	1 886	1 027	968	1 396	1 562	....	....
Net average annual loss (corrected by acidity destroyed in subsurface)									967	554

sonably trustworthy in representing the comparative effect of the high-calcium and the dolomitic materials.

The amount of residual carbonate found was, as an average, distinctly larger where dolomitic limestone had been added; that is, this form of stone was more lasting in the soil. However, notwithstanding its more lasting quality, this form of limestone was fully as effective in destroying the soil acidity as was the high-calcium limestone. In every case where high-calcium limestone had been applied, the average results showed a smaller amount of residual limestone, a larger annual loss of limestone, and less acidity destroyed. The data also show that the larger the amount of limestone applied, the more residual carbonate found, the more acidity destroyed, and the larger the loss of limestone from the surface soil.

EFFECT OF DEGREE OF FINENESS OF LIMESTONE UPON LOSS AND UPON ACIDITY

(Series 500 to 1000)

The data in Table 9 show the effect of the degree of fineness of the limestone upon the loss of limestone and upon the acidity in the surface soil. The figures are obtained by averaging the data from all plots receiving like applications of both the high-calcium and the dolomitic limestone. The results are the averages of six separate determinations from as many separate plots.

TABLE 9.—EFFECT OF DEGREE OF FINENESS OF LIMESTONE UPON LOSS OF LIMESTONE AND UPON ACIDITY IN THE SURFACE SOIL, SERIES 500 TO 1000: NEWTON FIELD, 1916

Average pounds calcium carbonate in 2 million pounds of surface soil (one acre about 0 to 6⅔ inches deep)

Fineness	¼ inch down	¼ to 1/10 inch	1/10 inch down	1/60 inch down	Burnt lime
		Limestone Found			
Light application	617	1 151	631	272	392
Medium application	1 613	2 117	1 025	659	648
Heavy application	3 899	4 776	3 558	3 545	1 822
		Acidity Found			
Light application	289	356	322	450	395
Medium application	437	222	367	468	348
Heavy application	75	64	110	136	56
		Acidity Destroyed			
Light application	631	620	709	637	746
Medium application	863	1 059	925	855	1 006
Heavy application	1 368	1 443	1 458	1 492	1 634
		Average Annual Loss of Limestone			
Light application	358	208	331	482	385
Medium application	721	523	871	995	953
Heavy application	1 351	1 080	1 419	1 417	1 869

In general, the finer the stone, the greater was the loss of limestone. The mill-run stone (¼ inch down) was practically as effective as any grade in destroying the acidity and in addition possessed better lasting qualities. The fine material present in this grade of stone seems to be sufficient for the immediate requirements of the soil, and the residual properties are of value in maintaining an alkaline reaction in the soil.

The annual loss of limestone from the surface soil, calculated from the residual carbonate and the acidity destroyed, was very high where the heavy application of limestone had been made, especially where the burnt lime had been used. It was therefore thought worth while to make some determinations of the total calcium to ascertain whether the actual loss of calcium was as large as these calculations indicated, or whether the apparent loss was due, in part at least, to the retention of the calcium in some form not shown by the method used or to the decomposition of the carbonate by the acidity which had been produced in the soil since the addition of the limestone. The calcium carbonate equivalent, as determined by the total calcium, is recorded in Table 10 for a few of the plots studied.

TABLE 10.—EQUIVALENT CALCIUM CARBONATE AS CALCULATED FROM THE DETERMINATION OF TOTAL CALCIUM, SERIES 500 TO 1000: NEWTON FIELD, 1916

Average pounds calcium carbonate in 2 million pounds of surface soil (one acre about 0 to 6⅔ inches deep)

Series	500	600	700	800	900	1000
Form of limestone	High-calcium	Dolomitic	High-calcium	Dolomitic	High-calcium	Dolomitic
Amount added, *lbs*	8 000	8 000	10 000	10 000	12 000	12 000
Plot No.	Total Lime in Soil					
13 (check)	9 645	9 385	9 510	9 645	9 630	9 742
17	16 277	12 552	18 472	12 950	20 375	13 852
18	15 765	12 102	18 245	13 755	18 590	15 340
19 (check)	9 925	10 175	10 012	9 125	9 657	11 000
Plot No.	Excess Lime in Treated Plots Over That in Check Plots[1]					
17	6 446	2 640	8 627	3 652	10 727	3 271
18	5 887	2 058	8 317	4 544	8 938	4 550

[1] These calculations are based upon the assumption that the original content of the treated plots lying between the two check plots varied uniformly from one plot to the next.

The annual loss of limestone from these plots, as calculated both from the carbon dioxid and from the total calcium determination, is recorded in Table 11. In calculating the loss of dolomitic limestone it has been assumed that such limestone contains 54 percent pure calcium carbonate based upon the theoretical composition of dolomitic limestone. From a study of these data it may be seen that the actual loss of calcium was considerably lower than is indicated when the calculation

TABLE 11.—ANNUAL LOSS OF LIMESTONE AS CALCULATED FROM CARBON DIOXID AND FROM TOTAL CALCIUM, SERIES 500 TO 1000: NEWTON FIELD, 1916

Average pounds calcium carbonate in 2 million pounds of surface soil (one acre about 6⅔ to 20 inches deep)

Amount of limestone added, *lbs*..	8,000		10,000		12,000		Average (10,000)	
	Calculated from—		Calculated from—		Calculated from—		Calculated from—	
	Carbon dioxid	Total calcium	Carbon dioxid	Total calcium	Carbon dioxid	Total calcium	Carbon dioxid	Total calcium
High-Calcium Limestone Treatment								
Plot No.	Series 500		Series 700		Series 900		Average of series	
17	1 471	444	1 437	392	1 903	364	1 604	400
18	1 426	604	2 017	481	2 199	875	1 881	653
Dolomitic Limestone Treatment								
Plot No.	Series 600		Series 800		Series 1000		Average of series	
17	1 253	889	416	925	2 025	1 697	1 231	1 170
18	1 462	1 197	1 741	454	2 371	1 021	1 858	891

is based upon the carbon dioxid determination. The average annual loss of limestone from the six high-calcium plots, as calculated from the carbon dioxid, was 1,742 pounds, while as calculated from the total calcium it was only 526 pounds. In the dolomitic series the average annual loss, as calculated from the carbon dioxid, was 1,545 pounds, while as calculated from the total calcium it was only 1,030 pounds. As an average of results from both high-calcium and dolomitic materials, the annual loss from the ground-limestone plot (No. 17), calculated from the carbon dioxid, was 1,417 pounds and from the burnt-lime plot (No. 18) 1,869 pounds; but when based upon total calcium, the loss was 785 pounds from ground limestone and 772 from burnt lime. These results indicate that the calcium was not removed from the soil more largely when applied in the form of burnt lime than when applied in the form of ground limestone.

INFLUENCE OF APPLICATIONS OF LIMESTONE TO SURFACE SOIL UPON ACIDITY IN THE SUBSURFACE AND SUBSOIL

(Series 500 to 1000)

The data for limestone and for acidity in the subsurface and the subsoil of Series 500 to 1000 are recorded in Tables 12 and 13. In general, the subsurface was found to be distinctly acid. It is very doubtful whether any of the small amounts of limestone found occasionally were due to the surface applications. Investigation showed that where limestone was found in the subsoil it extended in some

TABLE 12.—EFFECT OF LIMESTONE ON SUBSURFACE, SERIES 500 TO 1000: NEWTON FIELD, 1916
Average pounds calcium carbonate in 4 million pounds of subsurface (one acre about 6⅔ to 20 inches deep)

Series			500	600	700	800	900	1000	500	600	700	800	900	1000
Plot No.	Limestone applied to surface		Limestone found						Acidity found					
	Degree of fineness	Yearly, *lbs.*	High-calcium	Dolomitic	High-calcium	Dolomitic	High-calcium	Dolomitic	High-calcium	Dolomitic	High-calcium	Dolomitic	High-calci um	Dolomitic
1	No lime	...	...	...	...	...	...	...	5 536	5 436	3 468	2 764	4 912	6 496
2	¼ inch down	500	...	72	62	74	464	...	4 648	4 780	2 452	3 136	6 388	7 584
3	¼ to ⅒ inch	500	...	208	166	...	...	220	4 256	3 104	3 260	4 072	7 384	5 504
4	⅒ inch down	500	...	316	...	78	...	...	4 548	512	3 992	3 836	7 584	6 296
5	1/50 inch down	500	172	...	370	...	228	...	5 072	844	3 956	5 848	7 168	5 792
6	Burnt lime	500	...	1 920	...	74	76	...	7 120	1 680	4 768	4 900	5 488	6 368
7	No lime	...	...	...	...	...	...	...	7 148	2 112	4 980	5 012	3 248	5 152
8	¼ inch down	1 000	220	76	...	2 704	322	390	5 148	2 120	504	892	4 864	4 998
9	¼ to ⅒ inch	1 000	220	212	...	...	...	186	7 636	2 684	5 272	6 892	3 848	3 524
10	¼ inch down	1 000	728	76	...	...	150	118	6 632	1 152	7 936	7 460	4 912	5 148
11	1/50 inch down	1 000	...	212	...	896	...	50	5 284	1 112	7 172	6 152	4 268	5 604
12	Burnt lime	1 000	...	312	...	...	...	426	7 772	756	5 172	5 876	3 256	3 296
13	No lime	...	...	...	...	...	...	...	7 128	2 410	5 768	7 108	3 188	6 928
14	¼ inch down	2 000	152	222	...	272	...	562	6 436	3 436	3 836	5 832	2 372	5 504
15	¼ to ⅒ inch	2 000	...	286	...	1 320	922	254	7 336	5 000	4 160	4 816	2 124	9 380
16	¼ inch down	2 000	612	150	...	404	138	390	8 428	3 924	5 308	5 144	2 088	6 912
17	⅒ inch down	2 000	440	150	...	574	...	50	10 808	5 084	3 452	5 104	3 984	3 912
18	Burnt lime	2 000	152	...	...	404	434	...	9 720	5 960	1 944	5 020	5 352	980
19	No lime	...	...	...	...	...	...	...	6 296	7 524	3 676	6 772	6 444	6 508
Average for unlimed plots									6 527	4 370	4 473	5 414	4 448	5 776
Average for limed plots									6 723	2 810	4 212	4 999	4 739	5 386
Acidity destroyed									(−196)	1 560	261	415	−291	385

TABLE 13.— EFFECT OF LIMESTONE ON SUBSOIL, SERIES 500 TO 1000: NEWTON FIELD, 1916

Average pounds calcium carbonate in 6 million pounds of subsoil (one acre 20 to 40 inches deep)

Series			500	600	700	800	900	1000	500	600	700	800	900	1000
Plot No.	Limestone applied to surface		Limestone found						Acidity found					
	Degree of fineness	Yearly, *lbs.*	High-calcium	Dolomitic	High-calcium	Dolomitic	High-calcium	Dolomitic	High-calcium	Dolomitic	High-calcium	Dolomitic	High-calcium	Dolomitic
1	No lime.........	...	930	None	672	None	1 854	924	24 144	20 292	19 848	None	None	246
2	¼ inch down....	500	234	None	462	3 936	2 532	None	19 302	11 838	17 562	None	432	20 262
3	¼ to 1/10 inch....	500	570	936	1 128	8 052	None	None	18 108	1 806	19 308	None	24 408	28 344
4	1/10 inch down....	500	2 232	20 046	None	5 634	None	None	6 378	None	19 362	None	32 520	27 660
5	1/50 inch down....	500	2 484	33 264	666	666	366	462	5 874	None	3 930	2 532	29 880	24 306
6	Burnt lime......	500	3 726	23 688	2 478	None	5 688	228	312	None	312	26 190	618	20 796
7	No lime.........	...	8 292	27 282	1 446	None	6 150	None	3 018	None	1 146	25 248	804	23 604
8	¼ inch down....	1 000	2 688	15 042	672	936	None	462	5 556	None	10 008	27 480	13 158	20 676
9	¼ to 1/10 inch....	1 000	936	17 202	None	930	462	462	15 810	None	4 764	28 578	13 980	28 890
10	1/10 inch down....	1 000	3 570	14 112	234	None	1 542	462	12 090	None	2 196	24 432	60	19 626
11	1/50 inch down....	1 000	None	9 702	2 322	None	3 240	None	14 358	None	126	20 346	None	None
12	Burnt lime......	1 000	None	45 192	5 178	None	3 450	924	18 228	None	60	16 038	None	None
13	No lime.........	...	None	3 528	6 774	None	12 216	1 392	23 058	None	126	19 290	None	None
14	¼ inch down....	2 000	None	10 008	7 740	462	5 916	876	25 464	None	None	18 132	None	246
15	¼ to 1/10 inch....	2 000	672	1 860	2 694	462	9 780	1 764	28 680	186	None	23 880	None	12 906
16	¼ inch down....	2 000	672	1 440	3 306	None	12 948	2 178	24 234	126	126	19 668	None	6 072
17	1/50 inch down....	2 000	672	930	4 494	666	7 458	3 192	21 852	1 086	186	16 806	None	None
18	Burnt lime......	2 000	228	462	1 128	462	924	13 026	18 426	13 181	None	16 992	432	None
19	No lime.........	...	234	462	666	462	1 128	462	24 756	21 096	None	20 460	15 360	1 794

cases into the lower part of the subsurface, while the upper part of the subsurface was acid.

The subsurface soil of Plot 607 was sampled in three strata. The results show that per million pounds the stratum extending from 6⅔ to 14 inches below the surface contained 310 pounds of limestone and would have required 1,150 to neutralize the acidity present; while the stratum extending from 14 to 17 inches contained 200 pounds of limestone and would have required 320 pounds to neutralize the acidity; and the stratum extending from 17 to 20 inches contained 260 pounds of limestone and was neutral in reaction.

The results for the subsoil show clearly that in certain areas this stratum is distinctly acid, while in other areas an abundance of limestone is naturally present. The limestone present in the subsoil is native and not the result from any soil treatment. Examinations of the subsoil by three-inch strata show that the limestone usually increases with depth.

Thus, an examination of Table 14 will show that Plot 607, for example, which is an unlimed plot, contained 770 pounds of limestone per acre in the first 3-inch stratum of subsoil, and that the limestone increased steadily in amount to 2,820 pounds in the fifth stratum, and then decreased slightly; while every stratum was distinctly alkaline, which shows clearly that there was no unneutralized acidity present. In most other plots studied, quite similar results were obtained. However, in some plots the amount of limestone was not sufficient to neutralize the acidity present. Thus, in Plot 813 the amount of limestone was very small, while the degree of acidity was comparatively high; but it is interesting to note that the acidity decreased with depth.

In sampling the plots, the subsoil of Plot 813 was found to be plastic in nature, and in some places seemed almost impervious to water; while the subsoil of Plot 607, which contained an abundance of lime, was very moist and granular.

TABLE 14.—LIMESTONE AND ACIDITY IN VARIOUS STRATA OF THE SUBSOIL, 1916
Average pounds calcium carbonate per million pounds of soil

Plot No.	604	607	612	704	707	813	913
				Limestone Found			
20-24 inches	1 730	770	840	160	160	290	240
24-27 inches	6 120	1 490	1 430	250	170	160	790
27-30 inches	4 950	1 880	2 200	210	210	210	1 080
30-33 inches	3 400	2 530	3 000	160	410	1 120	2 300
33-36 inches	3 160	2 820	3 470	170	2 030	320	3 230
36-40 inches	2 080	1 710	1 920	160	1 247	280	2 600
				Acidity Found			
20-24 inches	Alk.	Alk.	Alk.	2 860	2 050	5 380	Neutral
24-27 inches	Alk.	Alk.	Alk.	4 340	1 860	4 760	Alk.
27-30 inches	Alk.	Alk.	Alk.	4 270	1 050	4 000	Alk.
30-33 inches	Alk.	Alk.	Alk.	3 150	290	3 290	Alk.
33-36 inches	Alk.	Alk.	Alk.	3 900	Alk.	1 840	Alk.
36-40 inches	Alk.	Alk.	Alk.	3 210	Alk.	350	Alk.

RESULTS FROM THE ODIN EXPERIMENT FIELD

Experimental work was begun on the Odin field in 1902. On Series 100 to 400 the rotation practiced is corn, soybeans (or cowpeas), wheat, and clover. Soybeans (or cowpeas) have been substituted for clover whenever it failed. Lime was applied uniformly to all limed plots (Nos. 3, 4, 5, 8, 9, and 10) prior to 1907, when it was decided to test the effect of different rates of liming by applying, once in four years, 2,000 pounds of ground limestone per acre to the west half of each of these plots and 4,000 pounds to the east half. Since 1907 the limestone has been applied in about this proportion once in each rotation in the fall for wheat. The rates of application, together with the dates, are given in Table 15. Plots 1 to 5 in each series are not tile-drained, while Plots 6 to 10 are tile-drained.

The plan of the Odin field is given on page 288. The half-plots are designated as east and west, tho as a matter of fact the eastern line of the field approaches northeast and southwest, following the direction of the Illinois Central railroad.

COMPARATIVE EFFECT OF LIGHT AND HEAVY APPLICATIONS OF LIMESTONE AND COMPARATIVE LOSS

(Series 100 to 400)

Samples of soil for analysis were taken in the spring of 1917. The east and the west halves of each of the limed plots were sampled separately; the unlimed plots were each sampled as a whole.

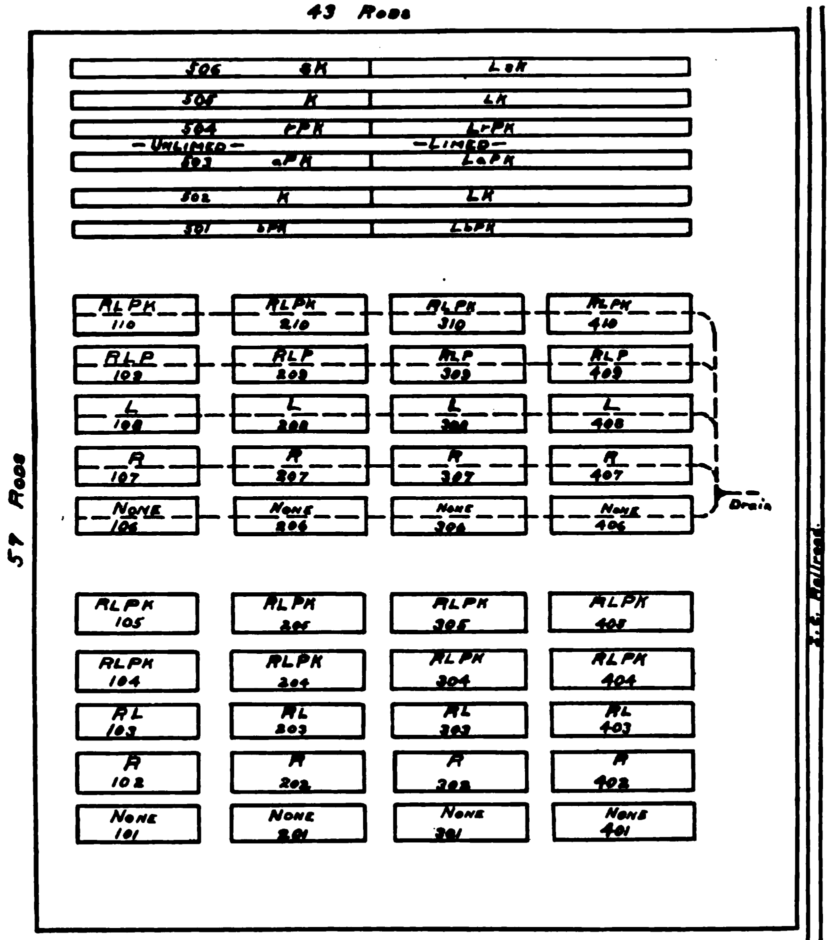
The data obtained from the surface soil are recorded in Tables 16 to 19. The results from all four series clearly show that in every case the application of either the light or the heavy amounts of limestone completely neutralized the acidity of the surface soil.

In every case where limestone had been applied, a considerable part of it was still present, and in general the amount found was proportional to the amount added. Furthermore, the limed soil was now found to be alkaline, except in four plots, three of which were neutral and the fourth but slightly acid. These exceptions all occurred where the light applications had been made. As an average of the twenty-four half-plots receiving limestone, those receiving the light applications still showed a limestone content of 1,362 pounds per acre, with an annual loss of 578 pounds; while the half-plots receiving the heavy applications showed an average content of 3,742 pounds per acre and an annual loss of 812 pounds. If limestone is added to acid soil only for the purpose of destroying the acidity of the surface soil, then the application of 2,000 pounds once in three or four years, after the initial acidity has been destroyed, would seem to be ample for keeping the soil alkaline. As an average, where the lighter applications had been made (one ton per acre once in four years), the loss (based

TABLE 15.—LIMESTONE APPLIED ON ODIN FIELD, 1902–1916
(Pounds per acre)

Series		1902[1]	1903[1]	1904	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	Total
100	E. half..	475	4 000	...	3 856	...	...	...	4 144	...	...	...	4 000	...	16 475
	W. half.	475	4 000	...	1 928	...	...	...	2 072	...	...	...	2 000	...	10 475
200	E. half..	475	4 000	...	3 800	...	...	3 000	...	...	...	1 200	4 000	...	16 475
	W. half..	475	4 000	...	1 900	...	...	1 500	...	...	...	600	2 000	...	10 475
300	E. half..	475	4 000	...	3 800	...	3 600	...	...	...	4 600	...	...	...	16 475
	W. half..	475	4 000	...	1 900	...	1 800	...	...	...	2 300	...	...	...	10 475
400	E. half..	475	4 000	...	...	3 600	...	...	...	4 000	...	...	...	4 000	16 075
	W. half..	475	4 000	...	...	1 800	...	...	...	2 000	...	...	...	2 000	10 275

[1] The applications recorded for 1902 and 1903 were of slaked lime.



PLAN OF ODIN EXPERIMENT FIELD

upon carbon dioxid) was only 75 percent as great as where the larger applications of two tons had been made.

From the data recorded in Tables 16 to 19 is computed an average annual loss from the surface soil of 812 pounds and 578 pounds, respectively, of limestone, where the heavier and the lighter applications had been made, as the average of the twenty-four limed half-plots. This loss is accounted for in part by the loss in drainage, and in part by the passing of the limestone down into the subsurface, there partially neutralizing the original acidity or even remaining as carbonate.

TABLE 16.—EFFECT OF LIMESTONE ON SURFACE SOIL, SERIES 100: ODIN FIELD, 1917
Average pounds calcium carbonate in 2 million pounds of surface soil (one acre about 0 to 6⅔ inches deep)

Plot No.	Treatment	Limestone				Soil acidity				Annual loss of limestone[2]	
		East half		West half		East half		West half			
		Added	Found	Added	Found	Found	Destroyed[1]	Found	Destroyed	East half	West half
101	0	...	...	...	...	152	...	152	...	...	...
102	R	...	...	...	...	354	...	354	...	...	...
103	RL	16 475	7 209	10 475	529	Alkaline	379	Neutral	379	576	646
104	RLP	16 475	3 429	10 475	1 489	Alkaline	379	Alkaline	379	846	577
105	RLPK	16 475	2 329	10 475	769	Alkaline	379	40	379	925	629
106	0	...	...	...	...	546	...	546	...	...	...
107	R	...	...	...	...	466	...	466	...	...	...
108	RL	16 475	3 621	10 475	2 181	Alkaline	379	Alkaline	379	832	529
109	RLP	16 475	3 841	10 475	1 661	Alkaline	379	Alkaline	379	816	565
110	RLPK	16 475	3 701	10 475	2 381	Alkaline	379	Alkaline	379	827	514

[1] Based upon the average of the unlimed Plots 1, 2, 6, and 7.

[2] In calculating the annual loss it has been assumed that the lime and limestone applied contained 95 percent pure calcium carbonate or its equivalent. The annual loss recorded is the average for fourteen years.

TABLE 17.—EFFECT OF LIMESTONE ON SURFACE SOIL, SERIES 200: ODIN FIELD, 1917
Average pounds calcium carbonate in 2 million pounds of surface soil (one acre about 0 to 6⅔ inches deep)

Plot No.	Treatment	Limestone				Soil acidity				Annual loss of limestone	
		East half		West half		East half		West half			
		Added	Found	Added	Found	Found	Destroyed	Found	Destroyed	East half	West half
201	0	...	...	...	...	312	...	312	...	...	...
202	R	...	...	...	...	244	...	244	...	...	...
203	RL	16 475	3 904	10 475	774	Alkaline	313	Alkaline	313	817	633
204	RLP	16 475	2 864	10 475	1 044	Alkaline	313	Alkaline	313	891	614
205	RLPK	16 475	3 341	10 475	544	Alkaline	313	Neutral	313	857	650
206	0	...	...	...	...	454	...	454	...	...	...
207	R	...	...	...	...	244	...	244	...	...	...
208	RL	16 475	3 217	10 475	1 397	Alkaline	313	Alkaline	313	866	588
209	RLP	16 475	4 264	10 475	1 742	Alkaline	313	Alkaline	313	791	564
210	RLPK	16 475	2 542	10 475	1 922	Alkaline	313	Alkaline	313	914	551

TABLE 18.—EFFECT OF LIMESTONE ON SURFACE SOIL, SERIES 300: ODIN FIELD, 1917

Average pounds calcium carbonate in 2 million pounds of surface soil (one acre about 0 to 6⅔ inches deep)

Plot No.	Treatment	Limestone				Soil acidity				Annual loss of limestone	
		East half		West half		East half		West half			
		Added	Found	Added	Found	Found	Destroyed	Found	Destroyed	East half	West half
301	0	...	...	...	...	406	...	406	...	...	...
302	R	...	...	...	...	498	...	498	...	...	...
303	RL	16 475	3 606	10 475	986	Alkaline	675	Alkaline	675	812	592
304	RLP	16 475	3 686	10 475	786	Alkaline	675	Alkaline	675	806	606
305	RLPK	16 475	2 626	10 475	946	Alkaline	675	Alkaline	675	882	595
306	0	...	...	...	...	1 080	...	1 080	...	...	...
307	R	...	...	...	...	718	...	718	...	...	...
308	RL	16 475	2 554	10 475	1 034	Alkaline	675	Alkaline	675	887	589
309	RLP	16 475	2 994	10 475	674	Alkaline	675	Alkaline	675	856	615
310	RLPK	16 475	2 534	10 475	814	Alkaline	675	Alkaline	675	888	604

TABLE 19.—EFFECT OF LIMESTONE ON SURFACE SOIL, SERIES 400: ODIN FIELD, 1917

Average pounds calcium carbonate in 2 million pounds of surface soil (one acre about 0 to 6⅔ inches deep)

Plot No.	Treatment	Limestone				Soil acidity				Annual loss of limestone	
		East half		West half		East half		West half			
		Added	Found	Added	Found	Found	Destroyed	Found	Destroyed	East half	West half
401	0	...	...	...	...	204	...	204	...	...	...
402	R	...	...	...	...	478	...	478	...	...	...
403	RL	16 075	1 606	10 275	1 306	Alkaline	416	Alkaline	416	946	574
404	RLP	16 075	3 406	10 275	3 306	Aklaline	416	Alkaline	416	818	431
405	RLPK	16 075	6 326	10 275	2 006	Alkaline	416	Alkaline	416	609	524
406	0	...	...	...	...	456	...	456	...	...	...
407	R	...	...	...	...	426	...	426	...	...	...
408	RL	16 075	6 844	10 275	1 984	Alkaline	416	Alkaline	416	572	526
409	RLP	16 075	6 044	10 275	1 284	Alkaline	416	Alkaline	416	629	576
410	RLPK	16 075	3 324	10 275	1 144	Alkaline	416	Neutral	416	823	585

In considering the annual loss of limestone from the light and the heavy applications, the following facts should be kept in mind: (1) The initial application of limestone was made in the fall of 1902, more than fourteen years previous to sampling; and (2) during the first five or six years, equal and somewhat larger applications of lime were applied to all plots, so that the average annual application for the light and the heavy applications had been equivalent to 745 and 1,169 pounds, respectively. During the latter years of the experiment, these amounts were about 500 and 1,000 pounds, respectively. From the data obtained, the loss for the light application may be computed as 66 percent and for the heavy application 54 percent; or 60 percent as an average of both the light and heavy applications.

INFLUENCE OF APPLICATIONS OF LIMESTONE TO SURFACE SOIL UPON ACIDITY IN THE SUBSURFACE AND SUBSOIL

(Series 100 to 400)

The amount of acidity in the subsurface of these four series was found in most plots to be very high but also very irregular. In many cases considerable limestone also was found. An examination of the data recorded in Table 20 will show distinct evidence that the appli-

TABLE 20.—EFFECT OF LIMESTONE ON SUBSURFACE, SERIES 100 TO 400: ODIN FIELD, 1917

Average pounds calcium carbonate in 4 million pounds of subsurface soil (one acre about 0 to 6⅔ inches deep)

Plot No.	Limestone found		Soil acidity		Limestone found		Soil acidity	
	East half	West half	East half	West half	East half	West half	East half	West half
	Series 100				Series 200			
1	....	....	3 656	3 656	....	....	2 552	2 552
2	....	....	4 760	4 760	....	....	2 892	2 892
3	1 418	None	320	5 360	824	184	1 640	4 560
4	778	698	3 680	1 600	144	24	1 640	1 560
5	1 338	1 498	2 360	3 040	554	24	800	4 120
6	....	....	4 792	4 792	....	....	4 860	4 860
7	....	....	3 220	3 220	....	....	2 020	2 020
8	3 028	348	3 480	5 960	None	None	1 840	1 960
9	628	588	3 200	2 520	None	None	280	160
10	1 588	1 028	3 040	5 680	186	266	2 000	280
	Series 300				Series 400			
1	....	....	3 916	3 916	....	....	3 692	3 692
2	....	....	5 368	5 368	....	....	4 440	4 440
3	320	160	2 400	320	644	404	3 520	600
4	400	240	620	2 720	564	324	2 320	480
5	160	320	2 360	3 200	2 124	None	1 080	3 200
6	....	....	4 264	4 264	....	....	1 984	1 984
7	....	....	5 908	5 908	....	....	932	932
8	928	328	2 320	3 120	1 760	800	1 520	2 320
9	2 808	978	680	3 880	3 080	1 440	160	2 320
10	1 128	528	1 880	3 640	1 600	640	880	3 040

cation of limestone to the surface soil is being felt in the subsurface, since much of the acidity of the subsurface has been destroyed; but owing to the irregularity of the limestone and the acidity in the subsurface of the individual plots, it is impossible to draw very fine distinctions from a study of individual plots. However, a comparison of the averages of the sixteen untreated plots and of the twenty-four half-plots on which heavy and light applications have been made shows a distinct influence by the limestone, as indicated in Table 21.

The acidity present in the check plots was found to be very high—3,703 pounds per acre as an average of sixteen separate determinations. Where the light applications of limestone had been made to the surface soil, the average of twenty-four separate determinations showed 2,735 pounds of acidity per acre in the subsurface, or a decrease of one-fourth of the acidity, with an average of only 451 pounds of limestone present; while where the heavy applications had been made, the average acidity had decreased to 1,834 pounds, or by about one-half of that originally present, and the average limestone present averaged 1,083 pounds, or about two and one-half times the amount where the light applications had been made.

TABLE 21.—EFFECT OF LIMESTONE ON SUBSURFACE SOIL: AVERAGES OF ALL PLOTS, SERIES 100 TO 400: ODIN FIELD, 1917

Average pounds calcium carbonate in 4 million pounds of subsurface soil (one acre about 6⅔ to 20 inches deep)

Number of plots	Lime added to surface soil	Limestone found	Acidity		Limestone net gain for subsurface
			Found	Destroyed	
16 plots........	None...........	None	3 703	......	......
24 half-plots....	Light application.	451	2 735	968	1 419
24 half-plots....	Heavy application	1 083	1 834	1 869	2 952

The data recorded in Table 21 indicate that as a result of the applications during fourteen years' time the sum of the limestone destroyed in neutralizing acidity in the subsurface and that found remaining in that stratum amounted to 2,952 pounds where the heavy applications had been made and 1,419 pounds where the light applications had been made. These figures represent an annual gain of 211 pounds and 94 pounds of limestone, respectively, in the subsurface stratum. If these numbers be subtracted from the annual loss from the surface soil, the unaccounted annual loss from that stratum amounts to 601 pounds and 484 pounds, respectively, for the heavy and the light applications.

The data for the limestone and acidity in the subsoil of these series is recorded in Table 22. The occurrence of limestone and acidity is very irregular and as one increases in amount the other decreases. The indications are that this limestone is native to the subsoil and has not been influenced at all by the applications to the surface soil.

TABLE 22.—LIMESTONE AND ACIDITY IN SUBSOIL OF SERIES 100 TO 400: ODIN FIELD, 1917

Average pounds calcium carbonate per acre in 6 million pounds of subsoil (one acre 20 to 40 inches deep)

Series		100	200	300	400	100	200	300	400
Plot No.	Treatment	Limestone found				Acidity found			
1	0........	17 112	19 908	None	1 452	None	None	18 564	9 732
2	R........	11 550	6 096	None	516	None	None	19 728	9 792
3	RL......	1 500	456	11 268	462	1 854	5 202	None	954
4	RLP....	462	462	522	5 970	15 978	5 988	5 430	None
5	RLPK...	1 194	2 808	516	1 194	2 106	216	9 126	11 976
6	0........	None	4 338	3 912	1 188	126	426	None	156
7	R........	960	8 262	None	1 914	246	None	1 056	5 334
8	RL......	1 374	1 182	15 468	None	396	246	None	24 126
9	RLP....	1 110	14 616	6 294	516	150	None	246	21 678
10	RLPK...	1 374	13 122	234	510	246	None	11 796	36 522

EFFECT OF DRAINAGE UPON LOSS OF LIMESTONE

(Series 100 to 400)

On Series 100 to 400, one-half of the plots of each series are tile-drained while the other half are undrained. Of the plots which receive limestone, then, there are twelve drained and twelve undrained. These plots furnish an excellent opportunity for studying the effect of drainage upon the loss of limestone from this type of soil, gray silt loam on tight clay. The average results for limestone found and for the annual loss of limestone are recorded in Table 23.

These results show that there is no distinct influence from tile drainage on the loss of limestone from this type of soil.

TABLE 23.—EFFECT OF DRAINAGE UPON LOSS OF LIMESTONE, AVERAGE OF ALL UNDRAINED AND DRAINED LIME-TREATED PLOTS, SERIES 100 TO 400: ODIN FIELD, 1917

Average pounds calcium carbonate in 2 million pounds of surface soil (one acre about 0 to 6⅔ inches deep)

Number of plots	Total limestone applied, average pounds per acre	Undrained		Drained	
		Limestone found	Annual loss	Limestone found	Annual loss
12	10 425	1 207	589	1 517	567
12	16 375	3 694	814	3 790	808

LIMESTONE AND ACIDITY IN SERIES 500

On Series 500 a five-year rotation of corn, oats, and three crops of hay (clover and timothy) is practiced. Altho this series is devoted primarily to a phosphate test, the east half of each plot is limed while the west half is not limed, so that limestone data are furnished as well as phosphate. The limed halves of these plots have received a total application of 11,000 pounds of limestone: 3,000 pounds in 1904, 3,600 pounds in 1909, and 4,400 in 1914.

The data for limestone and acidity in the surface soil, obtained in 1916, are recorded in Table 24.

TABLE 24.—EFFECT OF LIMESTONE ON SURFACE SOIL, SERIES 500: ODIN FIELD, 1916

Average pounds calcium carbonate in 2 million pounds of surface soil (one acre about 0 to 6⅔ inches deep)

Plot No.		Treatment	Limestone		Soil acidity		Annual loss of limestone
			Added	Found	Found	Destroyed	
501	E	LK bone P	11 000	1 694	Alkaline	294	819
	W	K bone P	......	......	294	......	....
502	E	LK	11 000	2 808	Alkaline	1 348	622
	W	K	......	......	1 348	......	....
503	E	LK acid P	11 000	1 962	Alkaline	1 450	690
	W	K acid P	......	......	1 450	......	....
504	E	LK rock P	11 000	1 758	Alkaline	810	766
	W	K rock P	......	......	810	......	....
505	E	LK	11 000	1 266	42	1 852	716
	W	K	......	......	1 894	......	....
506	E	LK slag P	11 000	2 214	Alkaline	334	768
	W	K slag P	......	......	334	......	....

In every case where limestone had been applied some of it could still be found in the surface. In only one of the limed half-plots was there any acidity found and then only 42 pounds per acre, while in all the other limed areas the soil was distinctly alkaline. Large amounts of acidity had been neutralized in all the limed plots. The annual loss of limestone varied from 622 pounds per acre to 819 pounds.

The data for the acidity and limestone in the subsurface of Series 500 is found in Table 25. It is evident that the average acidity of this stratum was greater in this part of the Odin field than in any other part. The application of limestone to the surface apparently resulted in the neutralization of considerable of the acidity in the subsurface. This conclusion is confirmed by a study of the results obtained from the subsoil (Table 26), where it may be seen that the subsoil of the limed part of the plots was more acid than that of the unlimed portion, clearly indicating that the limestone present in the subsurface resulted from the applications to the surface and was not derived from native limestone.

In Table 26 are recorded the data for the subsoil of Series 500. The subsoil of the limed portion of the plots was found to be distinctly more acid than that of the unlimed portion. In fact, in half of the cases the subsoil of the unlimed plots contained no acidity but con-

TABLE 25.—EFFECT OF LIMESTONE ON SUBSURFACE, SERIES 500: ODIN FIELD, 1916

Average pounds calcium carbonate in 4 million pounds of subsurface (one acre about 6⅔ to 20 inches deep)

Plot No.		Treatment applied to surface soil	Limestone		Soil acidity	
			Added to surface soil	Found	Found	Destroyed
501	E	LK bone P	11 000	None	1 596	5 744
	W	K bone P	.....	.....	7 340	.....
502	E	LK	11 000	None	1 348	2 900
	W	K	.....	.....	4 248	.....
503	E	LK acid P	11 000	472	2 324	3 460
	W	K acid P	.....	.....	5 784	.....
504	E	LK rock P	11 000	None	3 824	None
	W	K rock P	.....	.....	3 628	.....
505	E	LK	11 000	None	3 848	None
	W	K	.....	.....	3 720	.....
506	E	LK slag P	11 000	300	648	680
	W	K slag P	.....	.....	1 328	.....

TABLE 26.—EFFECT OF LIMESTONE ON SUBSOIL, SERIES 500: ODIN FIELD, 1916

Average pounds calcium carbonate in 6 million pounds of subsoil (one acre 20 to 40 inches deep)

Plot No.		Treatment applied to surface soil	Limestone		Soil acidity
			Added	Found	Found
501	E	LK bone phosphate	11 000	2 946	19 296
	W	K bone phosphate	......	1 194	648
502	E	LK	11 000	None	30 402
	W	K	......	2 430	282
503	E	LK acid phosphate	11 000	252	23 160
	W	K acid phosphate	......	1 500	336
504	E	LK rock phosphate	11 000	1 188	30 948
	W	K rock phosphate	......	10 014	None
505	E	LK	11 000	None	22 320
	W	K	......	12 864	None
506	E	LK slag phosphate	11 000	462	21 408
	W	K slag phosphate	......	6 240	None

siderable limestone, while the subsoil of the limed plots contained an amount of acidity that would have required several thousand pounds of limestone to neutralize it. Therefore, the reduced acidity and the limestone found in the subsurface of some of the limed plots must have resulted from the surface application.

CONCLUSIONS

1. From the evidence thus far secured, it appears that for the common prairie land of southern Illinois an application of one ton per acre of limestone once in three or four years is sufficient to keep the soil alkaline, or sweet, after the initial acidity has been destroyed by heavier applications.

2. Dolomitic limestone can be used successfully on acid soils. It is slightly more effective than high-calcium limestone in neutralizing the soil acidity, is more durable, and has no injurious effects on the crop yields.

3. As the result of nearly four years' work on the Newton field, there is no evidence that finely ground limestone is more effective in correcting soil acidity than is the total product from a ¼-inch screen, which contains both the finer material for immediate use and the coarser material for greater durability. This "mill-run" product seems to be the most economical form to use; but final conclusions must await further data concerning crop yields.

4. The destruction of the acidity of the soil is not a rapid process, for it is dependent upon the complete mixing of the applied limestone with the surface soil, which is a slow process. Limestone applied to the surface slowly penetrates into the subsurface. This process, however, requires considerable time. On the Odin field after fourteen years, one-half the acidity in the subsurface was neutralized where the larger applications had been made to the surface, and one-fourth where the lighter applications had been made. Applications of limestone to the surface soil seem to have no effect upon the acidity of the subsoil. The amount of native limestone found in the subsoil is a variable quantity. In some cases there is none present even at a depth of forty inches, whereas in other cases it extends upward even slightly into the subsurface.

5. The annual loss of limestone from the soil depends upon a number of factors, among which are the kind, the form, and the amount added. The data presented show that the annual loss of limestone is not so large as is generally assumed. As an average of all determinations, the annual loss from the surface twenty inches was 760 pounds per acre from the Newton field and 542 pounds per acre from the Odin field. A study of the total calcium indicates that the actual loss of bases may have been less than is shown by these figures, which are based upon the carbon dioxid and acidity determinations.

6. It is very evident from the data presented that chemical analysis may be depended upon to measure the acidity in the soil, the reduction in acidity due to the action of limestone applied, and also to find the limestone still remaining in the soil, whether from applications made or from a supply native to the soil.

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TWO ILLINOIS RHUBARB DISEASES

By FRANK LINCOLN STEVENS

URBANA, ILLINOIS, JANUARY, 1919

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TWO ILLINOIS RHUBARB DISEASES

By FRANK LINCOLN STEVENS, Professor of Plant Pathology, University of Illinois[1]

RHUBARB ANTHRACNOSE

(Due to *Colletotrichum erumpens*)

Attention was first called to this disease on market rhubarb in the stores of Champaign during the spring of 1918. It has since been repeatedly seen in the grocery stores and has been collected in the field in numerous localities, in both cases in such abundance as to show that it constitutes a real factor in rhubarb culture.

General Character

The disease, which is of fungous origin, consists of a soft rot of the petioles. As yet no natural field infection of other parts of the plant has been seen. The decayed spots usually are soft, watery, and translucent, oval in outline, with the long axis lengthwise of the petiole (Fig. 1). When they attain a length of somewhat more than a centimeter, the black, sporulating bodies (acervuli), smaller than fly specks, appear abundantly in the centers of the spots (Fig. 2). In advanced stages the whole petiole is covered with acervuli and is entirely soft and rotten (Fig. 3).

In the market usually only the milder cases of disease are found; petioles with numerous small rotten spots which have escaped the notice of the grower when preparing his product for sale. In the field, often all old petioles lying dead on the ground are thickly covered with acervuli, and older petioles slightly wilted are heavily infected. In general this disease appears much more abundantly on old plant parts than on fresh, vigorous parts, tho many vigorous, salable petioles are attacked, as is clearly evident from the abundance of the disease in the market as well as in the field.

This disease has been collected at Champaign and Urbana, Champaign county; at Kankakee and Bourbonnaise, Kankakee county; and near Anna, Union county; and is apparently of quite general occurrence.

The injury done is threefold. Even a small amount of the disease in a bunch of market rhubarb practically destroys the possibility of selling the bunch to a careful purchaser. In the field many petioles otherwise salable must be discarded on account of the rot. The premature death of infected petioles and consequently of the leaf blades lessens the general strength of the plant.

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[1] Assisted in the laboratory and in illustrating by Nora E. Dalbey.

THE FUNGUS

The rotten spots are uniformly occupied by a species of Colletotrichum, and in early stages of decay by this fungus alone. Young. watery, translucent spots which have not yet developed acervuli show the diseased tissue quite fully occupied by the mycelium. This mycelium is hyaline and of somewhat characteristic appearance in that the older parts are rather coarse (4 μ), conspicuously septate, and constricted at the septa (Fig. 4). Younger threads of mycelium are smaller, tapering to 2 μ at the extremities.

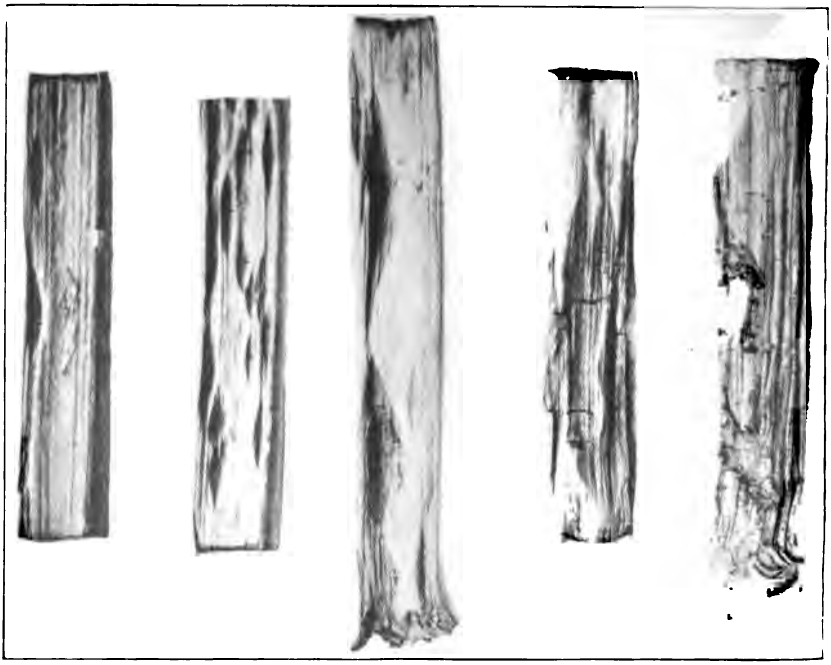

FIG. 1.—PETIOLES OF RHUBARB SHOWING VARIOUS STAGES OF DECAY RESULTING FROM COLLETOTRICHUM

The acervuli begin subcuticularly as an aggregate of hyphae, Fig. 5 (1), which soon ruptures the cuticle. When mature they are circular or oval and of an average diameter of about 200 μ. Soon after rupturing the cuticle, one or more setae appear, and in the mature acervulus the setae are numerous, usually from fifteen to

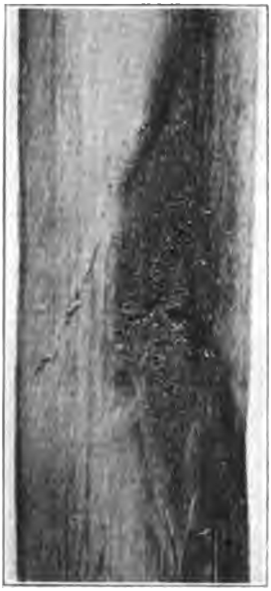

Fig. 2.—A single spot, enlarged. The minute pustules are the acervuli

twenty or more Fig. 5 (2, 3). Spores begin to form as soon as the cuticle ruptures, and the mature, undisturbed acervulus is covered with a mound of spores, often so deep as to cover even the tips of the setae.

The setae are black, somewhat pale at the tip, usually 3- or 4-septate, upward of 150 μ long, and about 7 μ thick at base, and with an acute tip, Fig 6 (1, 2).

The conidia are falcate (Fig. 7), quite uniform in size, measuring 22 to 29 μ by 3.5 μ, hyaline and continuous, and acute at each end. The conidiophores are shorter than the conidia, simple and continuous.

Isolation

The fungus was readily isolated by several of the usual methods:

1. By dilution platings of spores. In many cases the plates were entirely pure, with hundreds of colonies of the Colletotrichum.

2. By differential growth, by direct planting of bits of infected tissue upon poured corn-meal agar plates. When this method was employed, the Colletotrichum outgrew its contaminators, and could thus be easily isolated.

3. By direct planting of spores from drops of sterile water upon poured agar plates. The colonies so secured on corn-meal agar did not produce normal acervuli, but they did eventually produce characteristic conidia, and when transferred to sterile rhubarb gave abundant normal acervuli.

Culture Characters

On corn-meal agar plates the mycelium showed a tendency to darken in some cases, producing many filaments almost black, and giving to all the colonies a dark appearance. Analysis shows that the darkening of the colonies is due to an excessive production of ap-

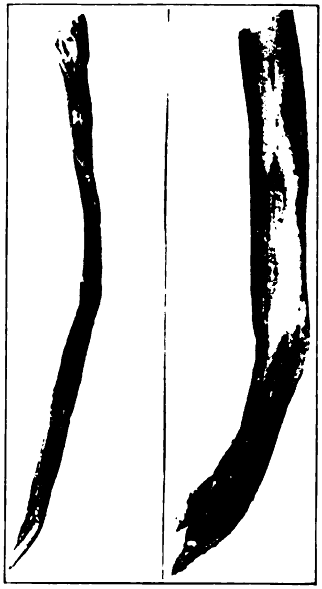

Fig. 3.—Advanced stages of decay of the rhubarb petioles

pressoria[1] and of structures which are morphologically appressoria. Often these are produced in large numbers in clumps which appear as black sclerotia-like bodies, several millimeters in diameter. This was particularly true where two colonies approached each other in the plate (Fig. 8). The structure of the component parts of such a spot is represented in Fig. 6 (3). A general view of several colonies on corn-meal agar is shown in Fig. 8. On this medium the acervuli are produced somewhat sparsely, after an interval of about a week.

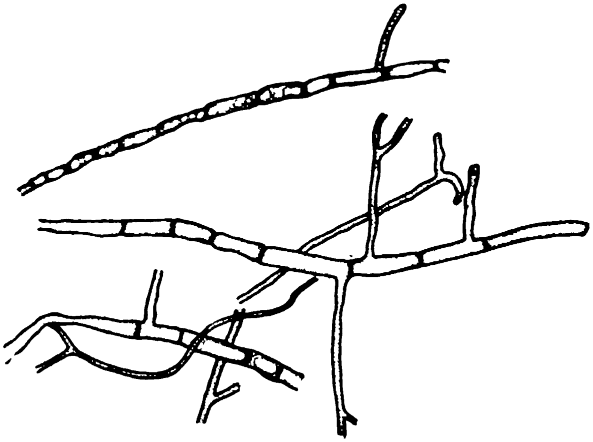

FIG. 4.—CHARACTERISTIC BRANCHING AND SEPTATION OF THE COLLETOTRICHUM MYCELIUM

When sterile (autoclaved) rhubarb was laid upon poured plates of corn-meal agar and then inoculated with the fungus, acervuli formed much more quickly than upon corn-meal agar alone, and spores were produced in much greater quantity. Thus abundant mature acervuli were present upon the bits of rhubarb at the end of three days.

Bits of rhubarb petioles were cut aseptically, and placed on poured corn-meal agar plates. Upon these growth was as upon the autoclaved rhubarb but decidedly more vigorous.

Corn-meal agar was poured into plates, then inoculated. When the colonies attained a diameter of about a centimeter, bits of raw, aseptic rhubarb were laid on the agar about a centimeter from the edge of the colony, in order to see whether the growth rate in this sector of the colony would be altered by the rhubarb. No such effect was noticeable, but it was found that tho the fungus made acervuli but very sparsely on the agar it did make them abundantly upon the bits of raw rhubarb upon the agar.

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[1] Hasselbring, H. Bot. Gaz. 42, 135, 1906; and Halsted, B.D., N.J. Agr. Exp. Sta. Rpt., 1892, 303.

On various autoclaved plugs the fungus grew well: e.g., on *Rumex crispus,* with typical acervuli but growth rather slow; on *Rumex acetosella,* similarly but growth more vigorous; on *Polygonum erectum* growth was scant and acervuli small; on *Polygonum lapathifolium* growth was similar to that on *Polygonum erectum* but slightly more vigorous; on Tropœolum stems, growth was very rapid and acervuli numerous, showing these stems to be more favorable than any other medium.

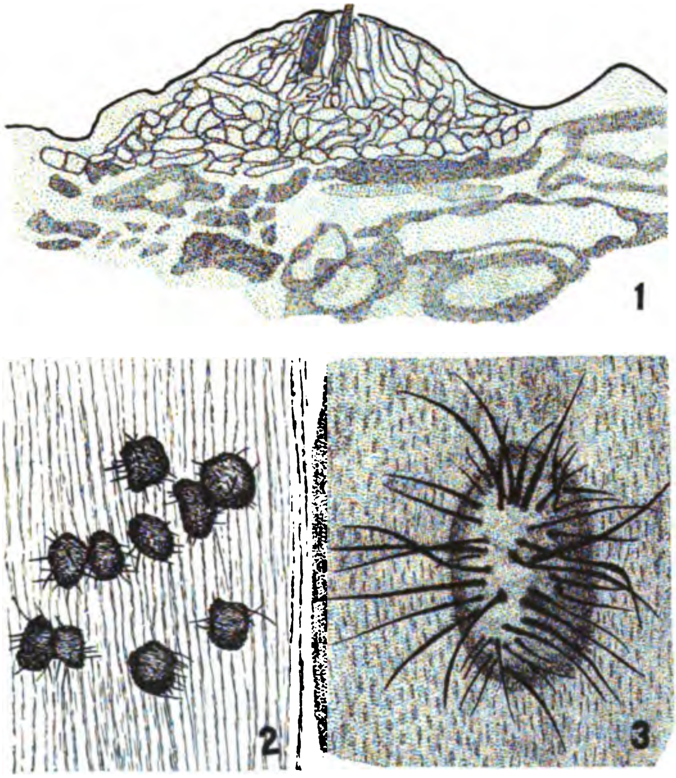

FIG. 5.—(1) A VERY YOUNG ACERVULUS; AN AGGREGATE OF MYCELIUM BELOW THE CUTICLE WITH INDICATIONS OF BEGINNINGS OF SETAE. (2) TYPICAL GROUP OF ACERVULI. (3) A TYPICAL ACERVULUS

On cabbage plugs the whole culture was less dark than on rhubarb plugs, the floccose aerial mycelium was white, and there was almost entire absence of appressoria, and of sclerotia, or other dark structures except those of the acervuli, which were very abundant and normal.

On rice there was an unusually large production of appressoria and sclerotia, giving the culture a striking black character (Fig. 9). In tubes on autoclaved rhubarb plugs, growth was vigorous, the surface of the plugs becoming closely covered with acervuli which produced spores about a week after inoculation. In the older portions the plugs were covered by a thin growth of aerial mycelium. On corn-meal agar in slant tubes the surface of the slant soon became covered with black sclerotia-like structures, and a ring of these structures was formed wherever the fungus touched the glass.

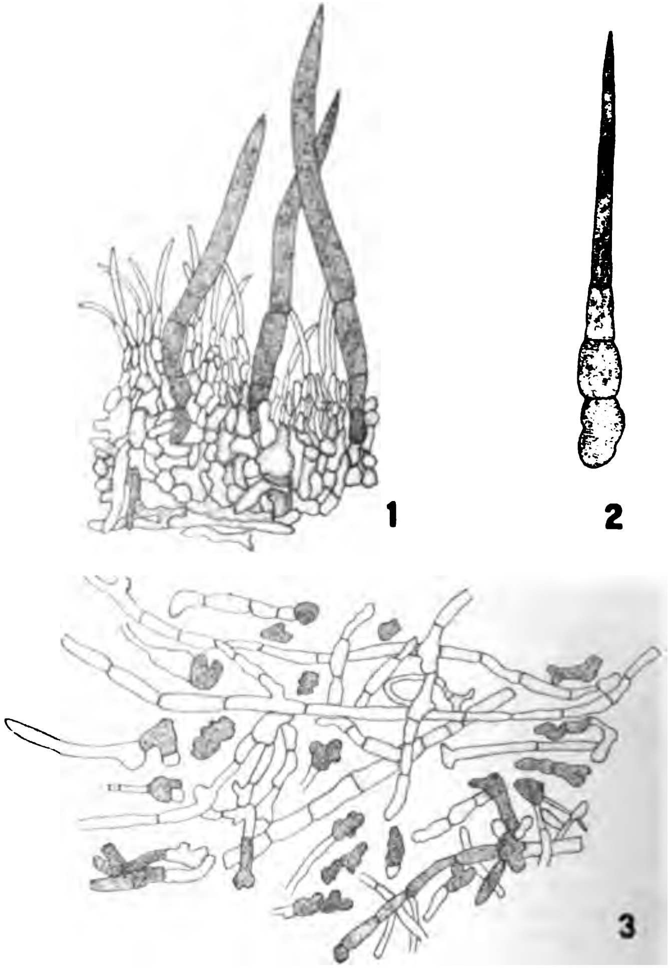

FIG. 6.—(1) DETAIL OF SETAE AND CONIDIOPHORES. (2) A SINGLE SETUM. (3) COMPONENT PARTS OF THE SCLEROTIA-LIKE BODIES PRODUCED IN AGAR PLATES

Inoculations

When spores from diseased tissue, or fragments of diseased tissue, or mycelium from a pure culture were inoculated into rhubarb petioles, the typical rot rapidly followed.

Tho the disease was not found in the field upon leaf blades, laying the spores upon leaf blades in a moist chamber in the laboratory resulted, in about seven days, in large, rotten, leaf spots bearing numerous typical acervuli. The disease also often appeared thru natural infection on leaf blades in the laboratory.

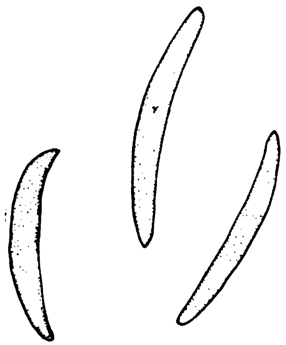

Fig. 7.—Spores of Colletotrichum

Germination of Conidia

Germination in water in hanging drop gave the usual characters of the anthracnose fungi; i.e., the spores usually became two-celled, developed a germ tube from one or both cells, and often from the germ tubes one or more appressoria (Fig. 10).

TAXONOMY

The fungus is a typical Colletotrichum. Never were setae absent from mature acervuli, nor is there any basal tubercular structure which would throw it into the genus Volutella. Colletotrichum as

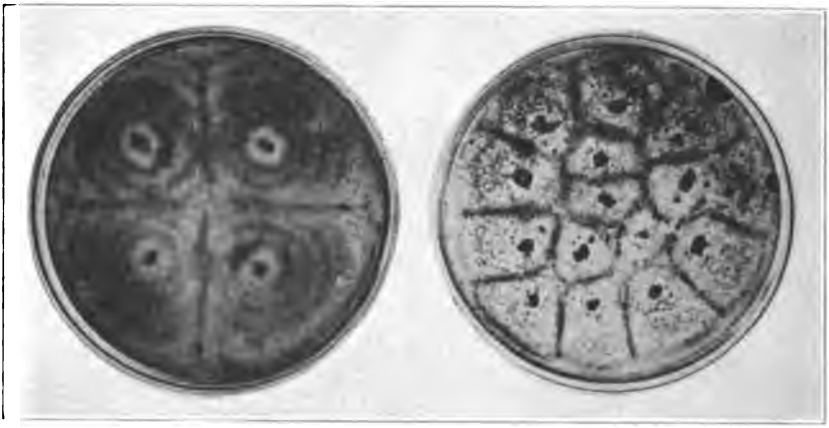

FIG. 8.—TYPICAL COLONIES ON CORN-MEAL AGAR
LEFT: FOUR COLONIES　RIGHT: MANY COLONIES
A dark line due to sclerotia-like bodies is evident in all cases when one colony meets another.

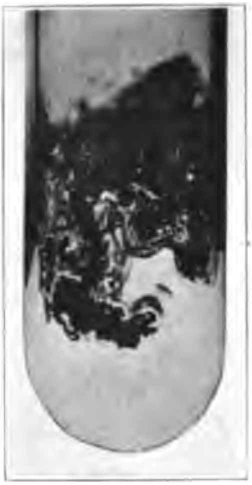

Fig. 9.—Growth of Colletotrichum on autoclaved rice

given by Saccardo[1] contains 113 form species. Of these, however, only 33 have falcate spores. There are 83 species of Volutella listed by Saccardo. The falcate-spored Colletotrichums are given in the accompanying table, together with such of the closely related genus Volutella as have falcate spores.

From this tabulation have been omitted such forms as are described as having spores "straight or slightly curved," "straight or curved," or similarly designated, on the assumption that such are not typically falcate, a character which were it present would be sufficiently obvious to be mentioned.

Accepting the descriptions as correct, Nos. 1 to 27 inclusive and Nos. 29, 38, and 43 do not agree in spore size with the fungus under consideration. Nos. 44 to 47 inclusive need not be considered. Nos. 28, 30 to 37, and 39 to 42 are so close in spore measurements to the species causing the rhubarb rot, that this might indeed, on that basis alone, be considered as co-specific with any one of them; nor is there any evidence from measurements of setae, except in the case of No. 37, that would bar such an assumption. Close inspection of the specific descriptions eliminates Nos. 40 and 41, which are clearly tubercular.

There then remains a group consisting of ten species which from the descriptions are indistinguishable from each other and from the

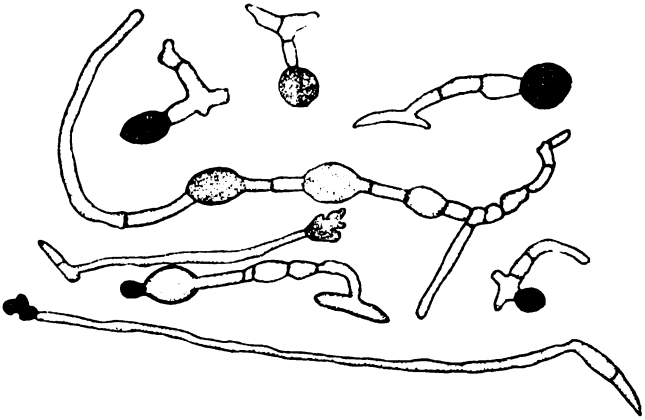

FIG. 10.—GERMINATING CONIDIA AND APPRESSORIA

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[1] Saccardo, Sylloge Fungorum.

FALCATE-SPORED FORMS OF COLLETOTRICHUM AND VOLUTELLA
Arranged in order of maximum spore length (μ)

No.	Saccardian		Name	Spore	Setae	Host
	Vol.	No.		Length×Breadth	Length×Thickness	
1	4	3234	*V. chalybea*	7–8×4–5	115–140×2.3	"fimo"
2	11	3676	*C. sanguisorbae*	9–10×2–2.5	80–100×3–6	Sanguisorbia
3	10	6851	*C. sphaeriaeforme*	10×3[1]	....	Menispermum
4	4	3237	*V. buxi*	10–11×3–4	100–120×4	Buxus
5	14	4026	*C. yuccae*	13×3.5	60×6	Yucca
6	10	6846	*C. pisi*	11–13×3–4	60– 90×6	Pisum
7	14	4019	*C. solitarium*	12–14×2.5–3	65– 75×2–3	Solidago
8	4	3227	*V. comata*	12–14×	....	Robinia
9	18	5034	*C. liliacearum*	12–17×2.5–3.5	70×5–5.5	Hemerocallus
10	16	3885	*C. piri*	13–18×3.5–5.5	....	Pirus
11	3	3843	*C. volutella*	14–18×2.5–3.5	300×5–6	Ulmaria
12	4	3263	*V. therryana*	15–18×3	150×1	Grasses
13	18	5014	*C. theobromicolum*	15–18×4–5	....	Theobroma
14	16	3882	*C. violae-tricoloris*	20×5	20– 70×	Viola
15	18	5772	*V. tristis*	11–20×2	400×7–8	Erica
16	10	6852	*C. spinaciae*	14–20×2.5–3	60– 75×4–4.5	Spinacia
17	16	3886	*C. elasticae*	16–20×4.5–5	200–250×	Ficus
18	10	6854	*C. gloeosporioides*	18–20×5–6	....	Hedera
19	16	4258	*V. violae*	15–21×3–4	....	Viola
20	4	3244	*V. fusarioides*	18–21×2–3.5	60– 72×5–7	Citrus
21	16	4262	*V. allii*	18–21×3–4	60–175×6	Allium
22	10	6847	*C. carpophilum*	16–22×2.5–4	60–100×5–6	Astragalus
23	22	7733	*C. ampelinum*	17–22×4–5	....	Vitus
24	16	3883	*C. rhoinum*	20–22×4–4.5	150–180	Rhus
25	22	7767	*C. vermicularia*	20–22×4	80– 90×4	Bromus
26	11	3679	*C. ailanthi*	22×4–5	90–135×5–9	Ailanthus
27	22	7741	*C. fructus* (*V. fructus*)	17–23×2.5–3.5	100–400×5–8	Pirus
28	10	6845	*C. brassicae*	19–24×	....	Brassica
29	22	7763	*C. sublineola*	15–25×4–5	30– 50×7	Sorghum
30	22	7744	*C. hedericola*	17–25×3.5	140×7	Hedera
31	3	3842	*C. erumpens*	25×5	150×4	Ruscus
32	11	3683	*C. falcatum*	25×4	100–200×4	Saccharum
33	22	7732	*C. vitis*	21–25×2.5	140–160×6–9	Vitis
34	22	7768	*C. cereale*	18–26×3–4	60–120×6–8	Grasses
35	11	3681	*C. omnivorum*	20–28×3–5	....	Funkia, Aspedistra, etc.
36	22	7753	*C. platani*	25–28×3–5	200	Platinus
37	3	3844	*C. lineola*	25–28×3.5–4	60×3	Andropogon, Umbellifers
38	22	7765	*C. antarcticum*	15–30×3–4	30–100×4–6	Poa
39	18	5025	*C. fici-elasticae*	20–30×3–4	200×6	Ficus
40	14	4493	*V. acalyphae*	25–30×2–3	150–210×4–7	Acalypha
41	14	4494	*V. oxyspora*	25–30×2–3	100–150×4–5	Beta
42	18	5036	*C. andropogonis*	30×4	100–150×8	Andropogon
43	22	7766	*C. janczewskii*	24–34×3–6	70–150×4	Poa
44	4	3245	*V. isabellina*	....	....	Salix
45	4	3232	*V. pulchella*	....	....	Branches
46	4	3252	*V. melaloma*	....	....	Carica
47	4	3226	*V. georginae*	....	....	Georgina

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[1] Spuriously 2 to 3 septate.

species described in this paper. These are designated as follows, from their oldest species, as the—

Colletotrichum erumpens group:

No. 31. *Colletotrichum erumpens* Sacc.
28. *C. brassicae* Schulz and Sacc.
35. *C. omnivorum* Hals.
32. *C. falcatum* Went.
39. *C. fici-elasticae* Zimm.
33. *C. vitis* Ist.
42. *C. andropogonis* Zimm.
30. *C. hedericola* Laub.
34. *C. cereale* Manns
36. *C. platani* Da Camara

In the present condition of knowledge concerning these forms, and until monographic work is completed regarding them, it seems wise to assume that the rhubarb Colletotrichum belongs to this group, and tentatively to refer to it as *Colletotrichum erumpens.*

RHUBARB LEAF SPOT

(Due to *Phyllosticta straminella*)

This disease was first collected at Bourbonnaise, Kankakee county, Illinois, where it was in great abundance in one field. Nearly every leaf in the plantation was affected with many spots, often occupying considerably more than half of the leaf area. A general idea of the

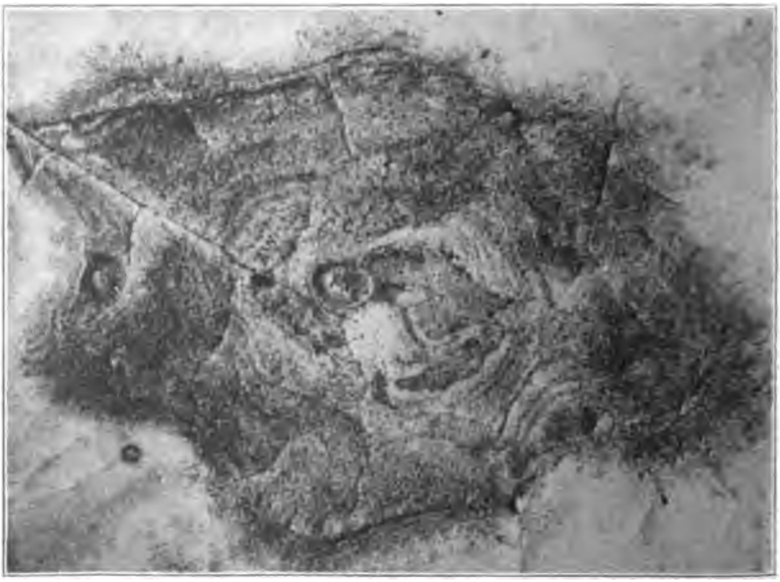

FIG. 11.—A SINGLE DISEASED SPOT OF THE PHYLLOSTICTA DISEASE ON RHUBARB

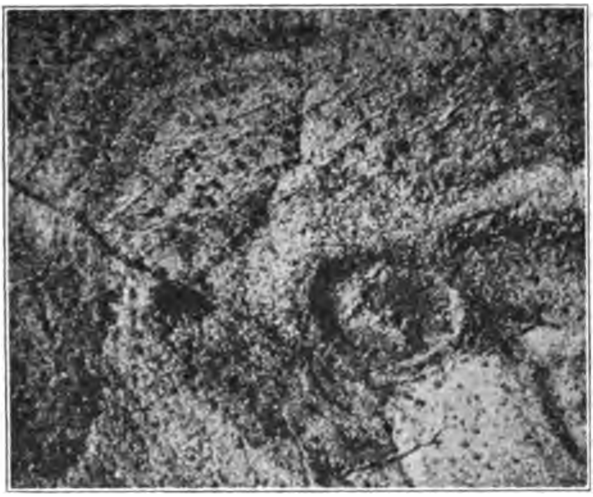

FIG. 12.—AN ENLARGED VIEW OF A PORTION OF THE SPOT SHOWN IN FIG. 11
The pycnidia are here clearly shown.

nature of the effect upon the leaf is given in the front-cover illustration. More detail of a single spot is shown in Fig. 11. Unlike the preceding disease this is not preeminently a disease of old leaves but even the comparatively young leaves may be seriously spotted. While mainly affecting the leaf blade, it has also been found upon the petioles. Upon the leaf blade the chief character is the irregularly circular dead spot, varying from a few millimeters up to several centimeters in diameter. The dead area is tan color and often dry and cracked or torn (see front cover). The margin of the spot is definite, with a rather sharp limitation between diseased and healthy tissue. Close inspection shows numer-

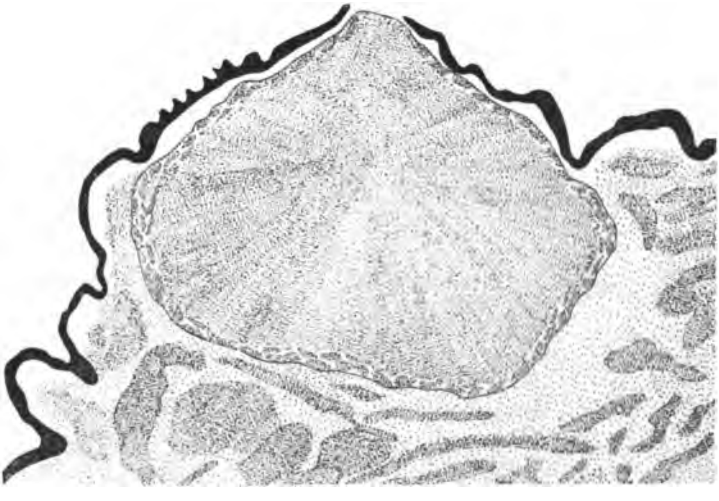

FIG. 13.—PHYLLOSTICTA. A PYCNIDIUM IN SECTION, SHOWING SUBCUTICULAR DEVELOPMENT AND SHAPE OF THE PYCNIDIUM
The cavity was entirely filled with spores.

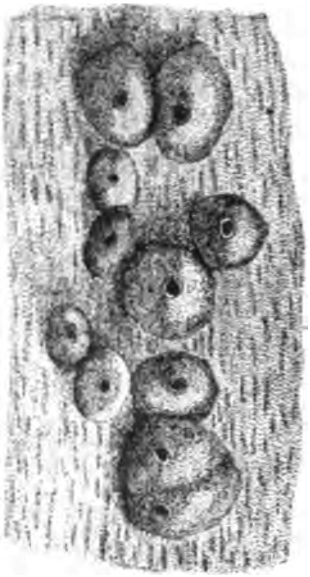

Fig. 14.—Phyllosticta, Pycnidia viewed from above

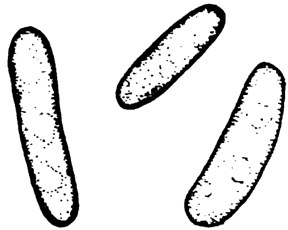

Fig. 15.—Phyllosticta spores from a leaf spot

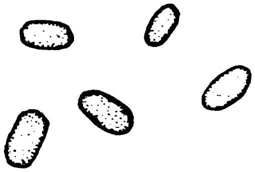

Fig. 16.—Phyllosticta spores, small type

ous very minute dark pustules (pycnidia) (Figs. 11 and 12). On petioles and stems the spots are oval lengthwise of the petiole, distinctly sunken, and quite dry. Sometimes a spot extends for nearly the whole length of a petiole, occupying perhaps only one side or part of one side of it.

In addition to collections at Bourbonnaise, others have also been made at Urbana, Kankakee, and Champaign. Specimens collected at Ladoga, Indiana, in 1916, by Dr. P. J. Anderson and at Racine, Wisconsin, by M. W. Gardener, bear the same fungus. When prevalent to the extent shown in the cover illustration, and to that degree on many leaves, as is the case in some fields, the drain on the vigor of the plants must be large.

THE FUNGUS

Microscopic examination invariably revealed the presence of a pycnidial fungus of the Phoma or Phyllosticta type. Fig. 12, an en-

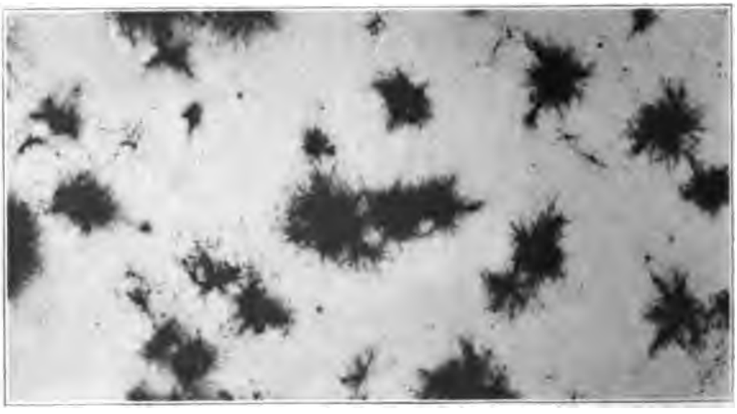

FIG. 17.—PORTION OF PETRI DISH SHOWING PHYLLOSTICTA COLONIES
This plating was made direct from rhubarb leaves.

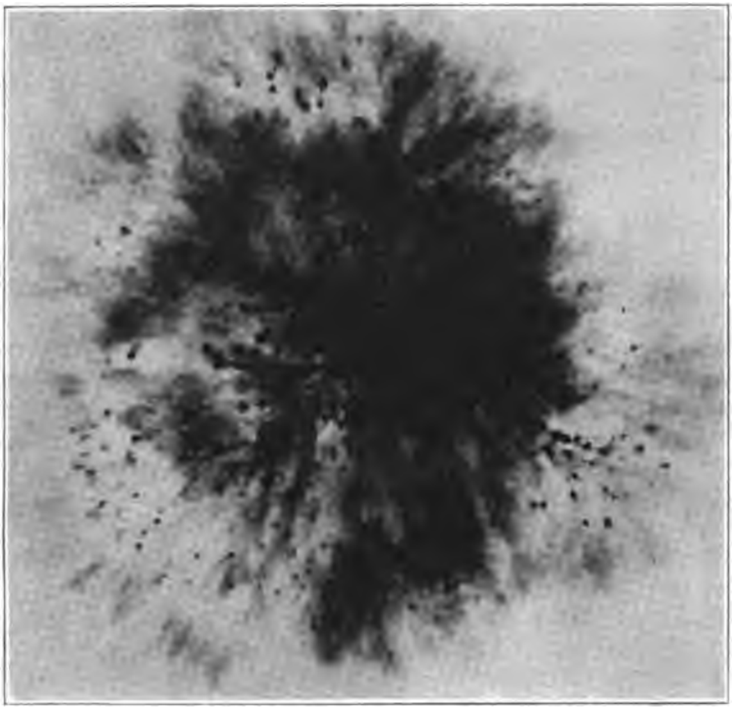

FIG. 18.—A SINGLE COLONY OF THE PHYLLOSTICTA ON CORN-MEAL AGAR

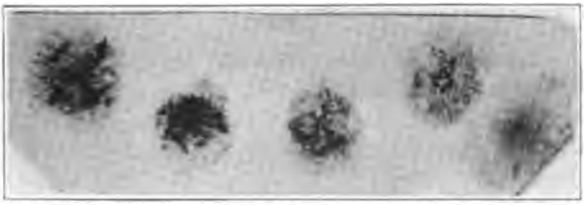

FIG. 19.—PORTION OF PETRI DISH SHOWING SEVERAL COLONIES OF THE PHYLLOSTICTA

larged view of a single spot, shows the numerous pycnidia. These are approximately circular, tan colored, about 120 to 150 μ in diameter, with an ostiole 20 to 30 μ wide (Fig. 14). Under appropriate conditions the spores issue in cirrhi or long agglutinated coils. From the leaf spot the spores are rather large for a Phyllosticta (10 to 19 μ by 4 to 5μ), and oblong (Fig. 15) and straight or very slightly curved. Specimens from the petiole and from some cultures to be described later gave a much smaller type of spore, as small as 4 to 5 μ by 1.5 to 5 μ (Fig. 16).

Isolation

The fungus was isolated on corn-meal agar in all of the ways noted on page 301, and with the same general results; i.e., the fungus grew readily and normally in culture (Fig. 17). Photographs of plates and colonies are given in Figs. 17, 18, and 19.

Culture Characters

On plates on corn-meal agar, the fungus grows rapidly and produces pycnidia quickly. When thickly sown, sporiferous pycnidia are produced in thirty-six hours; when more thinly sown, pycnidia are not so quickly produced. The colonies eventually become quite dark in the central region. The pycnidia arise uniformly by the simple meristogenous method. There is in corn-meal agar a very remarkable change in spore size from that exhibited by the same fungus when in its natural habitat. On this medium the spores are very rarely as long as 7 μ (Fig. 16). In very old cultures spores of somewhat larger size are found, but none as large as on the original leaf spots. On various autoclaved vegetable plugs the fungus grew well and formed numerous pycnidia normally. As with the Colletotrichum, Tropœolum stems were the most favorable medium. On cabbage the growth was exceptionally white. On rice the whole culture became black and was nearly like that of Colletotrichum (cf. Fig. 9).

The conidia germinated readily in hanging drops of water, nearly every spore germinating. There were formed no appressoria such as were invariably formed under similar conditions by the Colletotrichum.

TAXONOMY

Regarding this as a Phyllosticta and its spore measurements to be the extremes noted above; i.e., 4 to 19 μ by 1.5 to 5 μ, there are 829 species[1] listed by Saccardo from which, on a basis of spore size, it would be indistinguishable. Accepting the narrower limits of spore measurement obtained from the large spored forms from foliar material; i.e., 10 to 19 μ by 4 to 5 μ, there are 48 species listed by Saccardo from which it could not be distinguished by spore measurements. One only of these, however, occurs on any of the Polygonaceae. Ten other species of Phyllosticta are listed by Saccardo on Polygonaceae, but none of these has spores as large as the large-spored form described in this paper. All of these, with the exception of one, have maximum lengths of 12 μ, while in most of them the maximum length is below 8 μ. The one large-spored species, *P. straminella* Bres., described on *Rumex acestosa,* is given as having spores 12 to 20 μ long and is sufficiently close in morphology to the form under consideration to be regarded as the same species.

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[1] These facts are taken from a tabulation of the species of Phyllosticta listed by Saccardo, prepared for future publication by Mrs. E. Young True.

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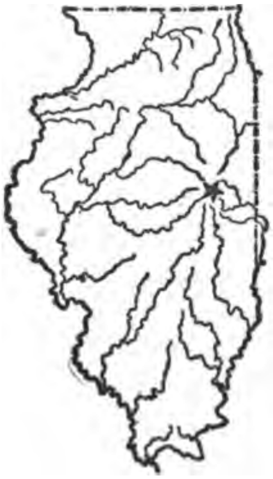
UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

BULLETIN No. 214

SPRING WHEAT FOR ILLINOIS

By W. L. BURLISON and R. W. STARK



URBANA, ILLINOIS, FEBRUARY, 1919

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Summary of Bulletin No. 214

Culture of Spring Wheat.—The cultural requirements of spring wheat are very much the same as for winter wheat. Page 315

Time to Sow Spring Wheat.—Spring wheat should be seeded early. Page 315

Four-Inch and Eight-Inch Drills Compared.—In so far as these experiments go, there is no evidence that the four-inch drill possesses any advantages over the eight-inch drill, with the ordinary rate of seeding. Page 316

Variety Tests.—At Urbana, in central Illinois, Illinois No. 1 has outyielded other varieties of spring wheat. At DeKalb, in northern Illinois, Marquis has given better yields than other spring varieties. Page 317

Yields and Value of Spring Wheat as Compared with Other Grains.—In central Illinois spring wheat will not produce as large yields as will the hardy varieties of winter wheat.

Owing to the very serious partial winter-killing of fall-sown varieties of wheat at DeKalb, Marquis spring wheat has made a four-year average yield of 2.5 bushels per acre in excess of Turkey Red, which is one of the hardiest of the winter varieties.

At Urbana, in central Illinois, Turkey Red winter wheat, Oderbrucker barley, and Sixty Day oats have given greater monetary returns per acre than any spring wheat. At DeKalb, in northern Illinois, Wisconsin Pedigree barley has given better returns than any other spring-sown crop. Page 318

SPRING WHEAT FOR ILLINOIS

BY W. L. BURLISON, CHIEF IN CROP PRODUCTION, AND
R. W. STARK, FIRST ASSISTANT IN CROP PRODUCTION

Within the last two years there has been a revival of interest in spring wheat, particularly in northern and to a lesser extent in central Illinois. The chief reason for this is the great demand for wheat made upon the American farmer by the war.

For the last two years the yields of spring wheat have been very encouraging; in fact, they have been better than had been expected. Spring wheat was grown quite commonly in northern Illinois many years ago, but for some reason not clear to all the practice was abandoned. For the central part of the state it would be unwise to be too enthusiastic about its production.

Spring Wheat Sections in Illinois.—For its best development, spring wheat requires a cool climate. Roughly speaking, the thirty-five counties in northern Illinois can safely include spring wheat in their systems of farming. Counties north of a line drawn between the southern boundaries of Kankakee and Mercer counties may be included in the primary spring-wheat belt of Illinois. Counties north of a line drawn between the southern boundaries of Edgar and Pike counties and south of the line mentioned above have produced very satisfactory spring wheat for the last two years.

CULTURE OF SPRING WHEAT

The cultural requirements of spring wheat are very much the same as for winter wheat. When spring wheat follows a small grain crop, fall plowing is certainly the best practice. This practice makes possible very much earlier seeding than would be possible if the land had to be plowed in the spring. The preparation of fall-plowed land is the same for spring wheat as it would be for any other spring-sown small grain. If spring wheat is to be seeded on stalk land, it would seem to be best to disk the land thoroly and seed then, rather than delay seeding for very long in order to plow.

TIME TO SOW SPRING WHEAT

Spring wheat should be sown early. In 1918 trials were made at Urbana, in central Illinois, to determine the effect of time of seeding upon the yield and quality of the crop. The varieties used were Illinois No. 1 and Marquis. The wheat was sown on ground that had been fall-plowed. At the time of the first sowing, the seed bed was in poor condition.

TABLE 1.—EFFECT OF DATE OF SOWING UPON THE YIELD AND QUALITY OF SPRING WHEAT

Plot	Date of planting	Illinois No. 1			Marquis		
		Bushels per acre	Weight per bushel	Percentage scab	Bushels per acre	Weight per bushel	Percentage scab
		bu.	*lbs.*	*percent.*	*bu.*	*lbs.*	*percent.*
1	March 6.......	28.9	60.8	1.0	29.6	59.0	2.0
2	March 16.......	23.5	59.4	.8	27.3	58.0	6.0
3	March 29.......	21.8	58.8	5.6	23.8	56.5	7.4
4	April 10.......	....	....	....	22.2	54.8	14.8

The earliest seeding gave the highest yield with both varieties. Each successive seeding produced consistently lower yields. The quality of the crop was also materially affected by the time of seeding. Without exception, the later the seeding the lower the weight per bushel. Scab (*Fusarium roseum*) affected the grain from each seeding, but the early-sown wheat was much less affected. Illinois No. 1 showed considerably less infection than did Marquis.

These results constitute the data obtained in only one year's work, but since they are so consistent they deserve consideration.

FOUR-INCH AND EIGHT-INCH DRILLS COMPARED

In recent years there has been considerable discussion about the value of the drill which plants the grain in rows 4 inches apart, as compared with the drill commonly used which distributes the same amount of grain per acre, in rows 7 to 8 inches apart. Table 2 gives some information on this point.

At DeKalb the wheat was sown in four-inch drill rows in 1916 and 1918 by using an ordinary eight-inch drill and "splitting the middles" the second round. In 1917 the four-inch rows were seeded with a regular four-inch drill. The eight-inch rows were sown with the same drill by stopping every other cup and doubling the rate of seeding. At Urbana the four-inch drill was used both in 1917 and in 1918 in the same manner as described for DeKalb in 1917.

With the exception of the first year during which the experiment was tried at DeKalb, the eight-inch rows gave slightly greater

TABLE 2.—COMPARISON OF YIELDS OF SPRING WHEAT OBTAINED BY SOWING IN FOUR-INCH AND IN EIGHT-INCH DRILL ROWS[1]

(Bushels per acre)

	DeKalb				Urbana		
	1916	1917	1918	Average	1917	1918	Average
Four-inch drill rows.......	36.3	22.8	27.5	28.9	32.2	23.9	28.0
Eight-inch drill rows......	34.7	24.1	31.2	30.0	33.0	25.3	29.1

[1] The yields given in this table are the averages of four trials each year, with the exception of those for Urbana, 1918. For that year the figures both for the four-inch and the eight-inch drill rows (standard rate of seeding) are the averages of three trials.

yields on both fields. The average yield at DeKalb for the three years was 1.1 bushels per acre in favor of the eight-inch rows. At Urbana the average for two years was also 1.1 bushels per acre in favor of the eight-inch rows.

Altho it is not yet possible to submit sufficient data upon which to base statements regarding the relative desirability of different rates of seeding, the present available information indicates that when the eight-inch drill is used for spring wheat, a satisfactory rate of seeding is from one and one-half to two bushels per acre.

VARIETY TESTS

CENTRAL ILLINOIS

TESTS AT URBANA, IN CHAMPAIGN COUNTY

The Illinois Experiment Station began a study of spring wheat at Urbana, in Champaign county, in 1912. In that year the Station obtained some spring wheat from a Champaign county farmer who had grown spring wheat with considerable success for a number of years. The original name of the variety is unknown. This wheat proved to be of sufficient worth in the trials to warrant distributing the surplus on a small scale in 1917. This variety has been designated as "Illinois No. 1."[1] It is a bearded variety and produces rather large, long heads. The straw is somewhat coarse and inclined to lodge.

The other three varieties; namely, Marquis, Red Fife, and Durum, were introduced into the trials in 1915. The yearly yields and the average yield of each variety for the last four years are reported in Table 3.

Illinois No. 1 gave an average yield for the last four years of 29.3 bushels per acre, which is 4.7 bushels per acre more than was made by Durum wheat, its closest competitor, and 7.9 bushels per acre more than Red Fife. Marquis produced almost 5 bushels less than Illinois No. 1.

TABLE 3.—YIELDS OF VARIETIES OF SPRING WHEAT GROWN AT URBANA[1]
(Bushels per acre)

Variety	1912	1913	1914	1915	1916	1917	1918	Average for last four years
Illinois No. 1....	24.7	18.2	13.9	19.6	27.9	43.1	26.7	29.3
Durum.........	....	....	....	14.4	24.6	31.9	27.6	24.6
Marquis........	....	....	....	14.6	21.8	36.3	25.1	24.4
Red Fife........	....	....	....	6.4	18.3	36.6	24.5	21.4

[1] The yields reported are the average of two trials of each variety in 1915 and 1916, and of four trials in 1917 and 1918.

---

[1] "Illinois No. 1" is a tentative name for this variety of spring wheat; in Bulletin 195 it is described as "home-grown."

NORTHERN ILLINOIS

TESTS AT DEKALB, IN DEKALB COUNTY

Spring wheat has been grown on the crop experiment field at DeKalb since 1907. In the early years a number of varieties were tried. Of this number Kubanka and Saskatchewan Fife were the only ones grown for a period of more than two years. These varieties appeared to be about equally adapted to northern Illinois, and under favorable conditions made quite satisfactory yields. A rather more systematic study of the adaptability of spring wheat for northern Illinois was begun in 1915. That year Marquis and Blue Stem were introduced, and two years later Durum and Illinois No. 1. Table 4 gives the yields of these varieties.

TABLE 4.—YIELDS OF SPRING WHEAT GROWN AT DEKALB[1]
(Bushels per acre)

Variety	1915	1916	1917	1918	Four-year average	Two-year average
Marquis	30.6	34.7	32.0	42.0	34.8	37.0
Blue Stem	19.6	21.3	28.4	29.6	24.7	29.0
Durum	....	....	17.2	44.4	....	30.8
Illinois No. 1	....	....	20.5	37.5	....	29.0

[1]The yields reported are the average of four trials each year.

It will be noted that the average yield of Marquis for the four years was 34.8 bushels per acre, which is 10.1 bushels per acre more than the yield of Blue Stem for the same period. The average yield of Marquis for the two years 1917 and 1918 was 37 bushels per acre. Durum ranked second, with an average yield of 30.8 bushels per acre, and Blue Stem and Illinois No. 1 each produced an average of 29 bushels per acre.

YIELDS AND VALUE OF SPRING WHEAT AS COMPARED WITH OTHER GRAINS

The data given in the following tables are suggestive of the relative monetary value of spring wheat as compared with several of the other commonly grown grain crops (winter wheat, oats, and barley). The values are based upon the average August price on the Chicago market for the ten years ending 1913. These prices were: wheat, 92.3 cents per bushel; oats, 37.8 cents; and barley, 60.2 cents. Since the beginning of the war, prices have become unusually high and so subjected to arbitrary control that recent values afford no satisfactory basis for comparison.

In the Urbana trials, Turkey Red winter wheat gave a four-year average yield of 44.6 bushels per acre valued at $41.16, while Illinois

No. 1, the best yielding variety of spring wheat, produced 29.3 bushels per acre worth $27.04. Oderbrucker barley produced 57.2 bushels per acre and ranked second in the value of the crop. Sixty Day oats ranked third, and Illinois No. 1, fourth.

TABLE 5.—URBANA: YIELD AND VALUE OF SPRING WHEAT AS COMPARED WITH TURKEY RED WINTER WHEAT, SIXTY DAY OATS, AND ODERBRUCKER BARLEY

Variety	Four-year average, 1915-1918	
	Bushels per acre	Value per acre
Illinois No. 1	29.3	$27.04
Durum	24.6	22.70
Marquis	24.4	22.52
Red Fife	21.4	19.75
Turkey Red (winter)	44.6	41.16
Sixty Day oats	78.5	29.67
Oderbrucker barley	57.2	34.43

The spring grains were grown in a four-year rotation of clover or soybeans, corn, corn, and spring cereals. The Turkey Red winter wheat was grown in a four-year rotation of clover, wheat, corn, and oats. The comparison is not entirely fair for the spring cereals, since in the rotation in which they are grown they are removed as far as the system will permit from the legume crop, while the winter wheat immediately follows the legume crop. There is also some difference in type of soil composing the fields devoted to the two rotations.

Notwithstanding the above mentioned advantages which the winter wheat has over the spring wheat, the comparison is instructive.

TABLE 6.—DEKALB: YIELD AND VALUE OF SPRING WHEAT AS COMPARED WITH TURKEY RED WINTER WHEAT, SWEDISH SELECT OATS, AND WISCONSIN PEDIGREE BARLEY

Variety	Four-year average, 1915-1918		Two-year average, 1917-1918	
	Bushels per acre	Value per acre	Bushels per acre	Value per acre
Marqius	34.8	$32.12	37.0	$34.15
Blue Stem	24.7	22.80	29.0	26.77
Durum	....	.....	30.8	28.43
Illinois No. 1	....	.....	29.0	26.77
Turkey Red (winter)	32.3	29.81	26.3	24.27
Swedish Select oats	68.8	26.00	75.4	28.50
Wisconsin Pedigree barley	62.9	37.87	69.3	41.72

At DeKalb, Marquis spring wheat gave a four-year average of 34.8 bushels per acre, which is 2.5 bushels per acre more than was yielded by Turkey Red. Assuming the grade to be the same, the Marquis wheat was worth $2.31 more per acre. During the last two years (1917 and 1918), Marquis yielded on the average 37 bushels per acre, or 10.7 bushels per acre more than Turkey Red, and was worth $9.88 more per acre. Wisconsin Pedigree barley proved the best paying crop of the several cereals tried.

These grains were grown in a four-year rotation consisting of clover, corn, spring cereals, and winter wheat. They were all grown in the same rotation, where the land received the same soil treatment.

Perhaps an even more direct comparison of the relative value of spring and winter wheat may be shown by the experience of the last two seasons (1917 and 1918) at DeKalb on certain plots devoted to winter wheat. Certain varieties of the winter wheat were so seriously winter-killed that it was necessary to disk them up in the spring and to sow spring wheat in their stead. The Marquis variety of spring wheat was used for this purpose. The yields of Marquis so substituted, and of Turkey Red, one of the winter varieties which survived, grown on the same series of plots, were as follows: In 1917: Marquis, 24.6 bushels per acre; Turkey Red, 29.7 bushels. In 1918: Marquis, 36.1 bushels; Turkey Red, 22.9 bushels. The averages for the two years show Marquis yielding 30.3 bushels per acre, as compared with 26.3 bushels produced by Turkey Red.

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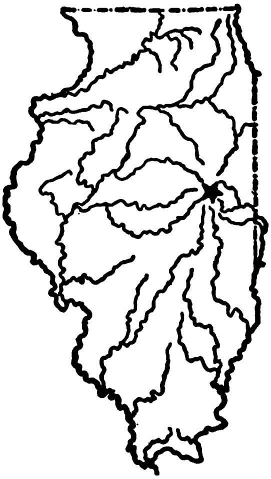
Agricultural Experiment Station

BULLETIN No. 215

A STUDY OF THE RELATIVE RELIABILITY OF OFFICIAL TESTS OF DAIRY COWS

BY W. W. YAPP



URBANA, ILLINOIS, FEBRUARY, 1919

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A STUDY OF THE RELATIVE RELIABILITY OF OFFICIAL TESTS OF DAIRY COWS

By W. W. YAPP, Associate in Dairy Husbandry

INTRODUCTION

The rearing of pure-bred cattle for dairy and breeding purposes has developed into a business of considerable financial importance, no small part of which has been brought about by the establishment of systems of Advanced Registry based upon milk and butter-fat production.

During the earlier years of the life of the various breed associations but few records were made, and the supervision of official testing was essentially a simple process. During this period it was extremely desirable to have a test which was easily operated and, at the same time, relatively inexpensive. The short-time test seemed to meet these requirements satisfactorily and therefore was placed in service in some of the breed associations.

Thru the general use of these short-time tests the cows, in at least one of these associations, made a very noticeable increase in butter-fat production. So great was this apparent increase that some breeders were led to believe that a longer test period might represent more accurately the real value of these cows as producers of milk and butter fat. This feeling spread over the country to a considerable extent, and it was with the idea of throwing some light upon the reliability of these short-time tests that the studies which are reported herein were begun.

These studies are confined entirely to the Holstein-Friesian breed of dairy cattle, owing partly to the fact that more tests of this breed were available for comparison and partly to the fact that the Holstein-Friesian Association made the seven-day test the basis of requirement for entry to the Advanced Register.

EXPLANATION OF TESTS

Thruout the course of this work references will be made repeatedly to the different test periods, the most important of which are: the seven-day test, the thirty-day test, the seven-day test eight months after calving, and the semiofficial long-time test, which usually covers a yearly period.

The seven-day test is an official test[1] which covers a period of seven consecutive days and may be begun as early as the seventh day after a cow's last calving. After satisfying the minimum requirements for this test, cows are admitted to the Advanced Registry and are designated as A. R. O. cows.[1] None of the other tests named will be accepted for publication by the Advanced Registry unless they are made by A. R. O. cows.[2]

---

[1] An official test is one in which the supervisor or tester weighs and tests the milk of each milking separately, being present at each and every milking during the entire testing period.

The thirty-day test is one which covers a period of thirty consecutive days and is governed by essentially the same rules as the seven-day test.

The seven-day test eight months after calving is also an official test, and may be begun not less than eight months (240 days) after a cow's last calving. In order that this test be accepted for publication in the Advanced Register, it must be preceded by a seven-day test made during the same lactation period; and there must be an interval of not less than 170 days between the two tests.

The semiofficial long-time test[3] may be begun not earlier than the fourth day after calving, and may be continued during that period of lactation or such consecutive part of it as the owner may desire, but it must not exceed 365 days in length. If this test is made of the production of an A. R. O. cow, and the results meet the established requirements, the test is accepted for publication by the Advanced Registry.

NATURE OF AVAILABLE RECORDS

All the records used in this work have been taken from the Holstein-Friesian Advanced Register, the official publication of the Holstein-Friesian Association. In collecting these data, all cows and heifers which had made semiofficial long-time tests with comparable[4] seven-day tests prior to May 1, 1915, were included. In addition, a study was made of all the thirty-day tests and of all the seven-day tests eight months after calving which had comparable seven-day tests and were made prior to May 1, 1913. In selecting the individuals which possessed semiofficial tests, only those with records covering a period of 330 days or more were included. All the tests used in this work are official tests except those designated as semiofficial.

---

[1] The letters A. R. O. stand for Advanced Registry Official and indicate that the test was official, that is, made under continuous supervision.

[2] A recent ruling of the Association has waived the seven-day test as a requirement for entry to the Advanced Registry for the semiofficial test.

[3] A semiofficial test is one in which the percentage of fat in the milk is determined by an official test that covers a period of not less than two consecutive days each month. The approximate fat production for the month is found by multiplying the weight of milk which the owner supplies by a number representing the percentage of fat found during the period of official test. The total fat production for the period is the sum of these various monthly credits.

[4] In this study a comparable test is considered as one that is made by the same cow during the same lactation period. A cow might have a seven-day test made as a two-year old and a semiofficial test made as a mature cow, but these would not be comparable and therefore would not be given consideration in this study.

PLAN OF INVESTIGATION

In this study the semiofficial test has been taken as the standard and has been used as the basis for comparison. After checking the accuracy of the semiofficial test, an attempt has been made to determine its relationship to the seven-day test with respect to the percentage of fat which each carries. The thirty-day test and the seven-day test eight months after calving have each been compared with their comparable seven-day tests. To show the extent to which the seven-day tests may be used as an indication of yearly production, correlation coefficients have been calculated for the seven-day and the yearly tests, both for milk and for fat.

ACCURACY OF THE SEMIOFFICIAL TEST

It became evident early in this study that it was necessary to establish some basis of comparison for the different records. Naturally, the yearly record, since it covered a longer period, suggested itself as the standard by which the other records might be measured. It was realized, however, that the method employed in determining yearly production had been criticized by some for its lack of accuracy, and it was decided advisable to check the accuracy of this test, in so far as possible.

For a number of years, a daily record, to which each milking contributed proportionately, has been kept of the production of each cow in milk in the University herd. A number of these cows have also made semiofficial records. For convenience, the test regularly used in the University herd is designated as the "continuous test."[1]

In order to measure the relationship between these two methods of testing, the mean, the standard deviation, and the coefficient of variability are calculated for the fat production as obtained by each.[2] Tables 1 and 2 present the results.

---

[1] In the University herd the continuous test is conducted essentially as follows: Each milking is weighed and sampled. The sample taken, which represents an aliquot part of the milk, is placed in a closed bottle containing a small amount of preservative. At the end of each week the composite thus formed is tested for butter fat. The fat percentage found is taken as the average for the week, and when multiplied by a number representing the pounds of milk for that period, gives the weekly fat production. The sum of these various weekly productions constitutes the yearly butter-fat record.

[2] It is not necessary to compare these two methods of testing with respect to the amount of milk produced, since both methods require that the milk of each and every milking be accurately weighed and recorded.

TABLE 1.—YEARLY BUTTER-FAT PRODUCTION OF THIRTY COWS IN THE UNIVERSITY HERD, AS ASCERTAINED BY THE CONTINUOUS TEST

Class interval; fat production, *lbs.*		Frequency	Average deviation	F(AD)		$F(AD)^2$
	250—300	1	-3	-3		9
	301—350	3	-2	-6		12
	351—400	9	-1	-9	-18	9
425.5	401—450	10	0	0		0
50	451—500	3	+1	+3		3
	501—550	3	+2	+6		12
	551—600	1	+3	+3	+12	9
		30			-6	54

Mean: 425 — 10.00 = 415.50 ± 8.12
Standard deviation: 66.1 ± 5.76
Coefficient of variability: 15.90 ± 1.38

TABLE 2.—YEARLY BUTTER-FAT PRODUCTION OF THIRTY COWS IN THE UNIVERSITY HERD, AS ASCERTAINED BY THE SEMIOFFICIAL TEST

Class interval; fat production, *lbs.*		Frequency	Average deviation	F(AD)		$F(AD)^2$
	251—300	1	-3	-3		9
	301—350	4	-2	-8		16
	351—400	10	-1	-10	-21	10
425.5	401—450	8	0	0		0
50	451—500	4	+1	+4		4
	501—550	2	+2	+4		8
	551—600	1	+3	+3	+11	9
		30			-10	56

Mean: 425.5 — 16.65 = 408.85 ± 8.14
Standard deviation: 66.25 ± 5.77
Coefficient of variability: 16.20 ± 1.41

From a study of these tables it is observed that the mean, or average, production of the cows when making the continuous test was 415.5 pounds of fat ± 8.1 pounds; whereas the semiofficial test of the production of the same cows during the same period shows 408.9 pounds ± 8.1. This slight difference between the averages shown by the two different methods of testing is not regarded as significant.

The standard deviation in the case of the continuous test is 66.1 ± 5.8; while that for the semiofficial is 66.25 ± 5.8. Again there is a rather unusually close relationship between the two methods of testing. The coefficient of variability in the case of the continuous test is 15.90 ± 1.38 percent; whereas, in the case of the semiofficial test, it is 16.20 ± 1.41 percent, a difference that is not significant.

These data are not held to be comprehensive, but so far as the limited number of records involved can be used to indicate the relation between the two tests, they seem to indicate very little difference.

These data support the general opinion that the semiofficial test is a fairly accurate measure of the producing ability of cows.

RELATION OF FAT PERCENTAGE TO TEST PERIOD

SEVEN-DAY TEST

In the study of the percentage of fat in the milk during these various test periods, it is necessary to deal in averages. Table 3 shows the variation in fat percentage between low and high fat production for the seven-day test. The data are presented graphically in Fig. 1.

TABLE 3.—SEVEN-DAY TEST: RELATION BETWEEN AMOUNT OF FAT AND PERCENTAGE OF FAT

Class interval; fat production	Frequency	Milk production	Fat test	Fat production
lbs.		*lbs.*	*percent*	*lbs.*
Under 9.00	28	268.4	3.14	8.415
9.01—12.00	192	318.5	3.36	10.697
12.01—15.00	350	381.0	3.53	13.441
15.01—18.00	374	453.1	3.64	16.479
18.01—21.00	214	503.3	3.84	19.325
21.01—24.00	114	574.6	3.97	22.837
24.01—27.00	18	587.1	4.26	25.025
27.01 and over	4	567.5	5.15	29.226

From this study of the seven-day test it is shown that low fat production is accompanied by a correspondingly low fat percentage, and high fat production accompanied by a relatively high fat percentage. Individuals that produced on the average 8.415 pounds of fat for the seven-day period produced milk having an average fat

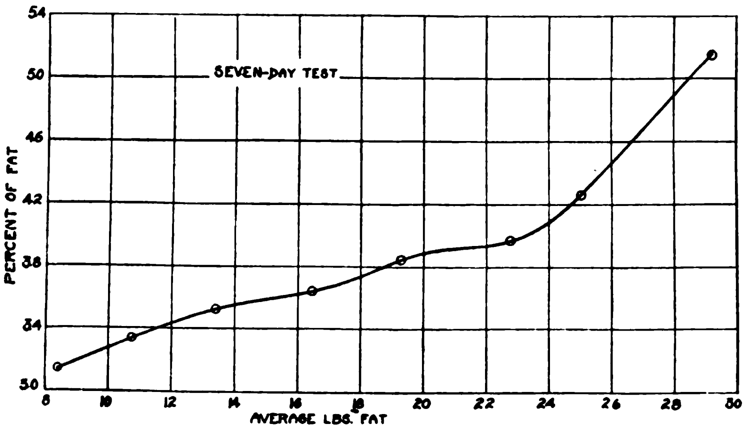

FIG. 1.—SEVEN-DAY TEST: RELATION BETWEEN AMOUNT OF FAT AND PERCENTAGE OF FAT

test of 3.14 percent; whereas those producing an average of 25.025 and 29.226 pounds of fat for the same period produced milk having an average fat test of 4.26 and 5.15 percent, respectively; the difference between the lowest and the highest group in percentage of fat being 2.01 percent. Not only is the increase in the amount of fat produced, accompanied by a corresponding increase in the percentage of fat, but there is also an increase in milk production, tho not in proportion to the fat increase.

One of the noticeable features of the curve shown in Fig. 1 is its smoothness, there being a tendency for it to rise uniformly with the increase in fat production. This fact indicates that high butter-fat records for the seven-day period are secured, to a rather high degree, by high fat tests rather than by unusually heavy milk production.

SEMIOFFICIAL TEST

Table 4 and Fig. 2 show the relation between amount of fat and percentage of fat as recorded under the semiofficial test.

TABLE 4.—SEMIOFFICIAL TEST: RELATION BETWEEN AMOUNT OF FAT AND PERCENTAGE OF FAT

Class interval; fat production	Frequency	Milk production	Fat test	Fat production
lbs.		*lbs.*	*percent*	*lbs.*
251—350	83	9 583.7	3.35	320.585
351—450	349	12 100.6	3.35	405.382
451—550	410	14 747.0	3.39	499.977
551—650	270	17 142.1	3.47	595.983
651—750	122	19 875.9	3.48	691.735
751—850	35	21 720.8	3.62	787.161
851—950	16	24 453.3	3.65	892.332
951—1050	9	26 225 6	3.79	993.367
1051—1150	1	24 612.8	4.53	1 116.050

A study of this table shows that under the semiofficial test there is a difference between the fat percentage of low butter-fat production and that of high butter-fat production, but this difference is not nearly so great as in the case of the seven-day test. In the semiofficial test, low butter-fat production is not accompanied by an extremely low fat percentage nor is high butter-fat production accompanied by an extremely high fat percentage. In low production (320.585 pounds of fat for the yearly period) the average percentage of fat was 3.35; whereas in high production (993.367[1] pounds of fat for the same period) the average percentage of fat was 3.79, a variation in fat test between low and high production of only 0.44 percent.

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[1] The last group, in which the variation is between 1,051 and 1,150 pounds of fat, is not considered.

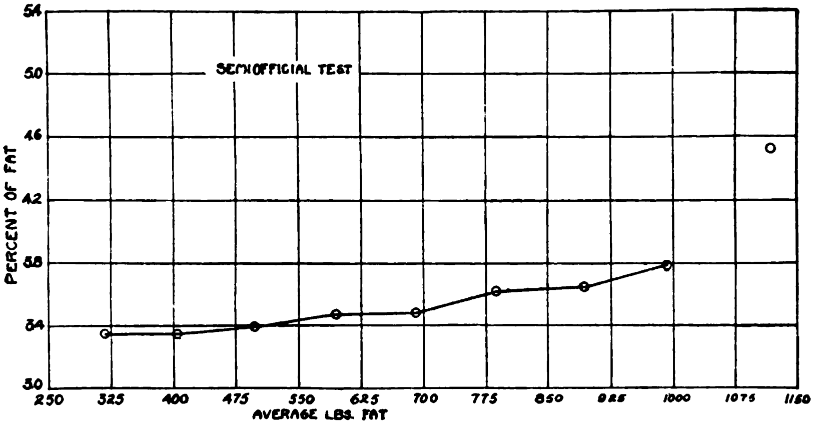

FIG. 2.—SEMIOFFICIAL TEST: RELATION BETWEEN AMOUNT OF FAT AND PERCENTAGE OF FAT

The curve in Fig. 2 shows a tendency to rise, but the rise is much less marked than in the case of the curve in Fig. 1. The tendency in the semiofficial test seems to be to secure high fat production by means of an increased milk production rather than thru a very high fat percentage. The difference in the results from these two tests is brought out more clearly when the two curves are superimposed upon the same graph. This is possible since both curves are drawn to the same scale. Fig. 3 shows this relationship.

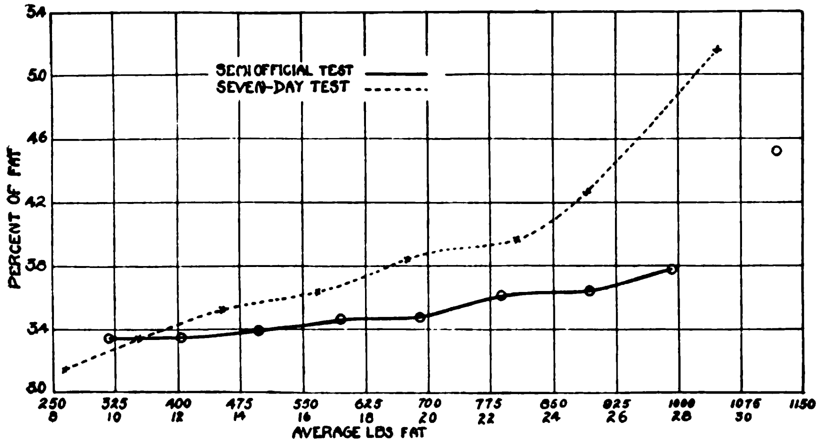

FIG. 3.—COMPARISON OF SEVEN-DAY AND SEMIOFFICIAL TESTS WITH RESPECT TO THE RELATION BETWEEN AMOUNT OF FAT AND PERCENTAGE OF FAT

These curves correspond very closely in fat percentage in the case of low butter-fat production. As the production increases, however, there is a tendency for the curves to separate, with the seven-day test showing the higher percentage of fat. The difference between the two is greatest in the case of high butter-fat production, the maximum difference being as great as .47 percent.

VARIABILITY IN PERCENTAGE OF FAT

Not only is the percentage of fat for the seven-day test higher than that for the semiofficial period, but it is also much more variable. Fig. 4 shows this variability.

The seven-day test, it will be noted, carries not only a high average fat percentage, but in a number of single cases the fat tests are exceptionally high. The spread of the curve which represents the fat percentage for the seven-day test indicates considerably more variability than is shown by the semiofficial test. The curve representing the percentage of fat for the semiofficial test indicates that there is variability but that the variability is less than in the preceding case. This curve is nearly symmetrical in form and approximates what is called the normal probability curve.

Altho these curves show that there is a certain variability in fat percentage, they do not measure this variability. To determine the variability within each of these tests, standard deviations and coefficients of variability have been calculated.

SEVEN-DAY TEST

Table 5 shows the variability in fat percentage for the seven-day test. It is observed that the mean, or average, fat percentage for the 1,295 records considered is 3.679 ± 0.01. This percentage is not regarded as high for a single individual or a small group of selected individuals of the Holstein-Friesian breed, but it is considered high for a large and fairly representative group. The small probable error of ± 0.01 indicates that the records of the 1,295 cows considered were adequate to determine relatively accurately the average percentage of fat produced by the class of cows that have completed seven-day records. Altho the mean gives a satisfactory measure of the average fat percentage for all cows of the class that have completed seven-day tests, it does not give any idea as to whether or not some of the cows produced milk exceptionally high or exceptionally low in percentage of fat.

The standard deviation, on the other hand, describes this variability. For the seven-day test we find a standard deviation of .5256 ± .007. This is regarded as a fairly high degree of variability. The coefficient of variability, 14.29 ± .18 percent, gives the same general result.

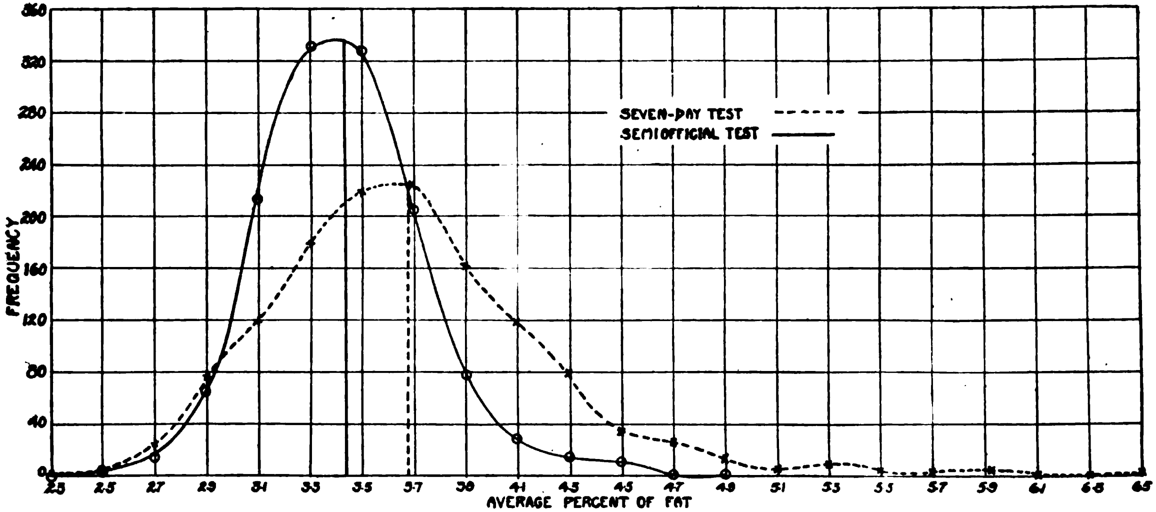

FIG. 4.—COMPARISON OF SEVEN-DAY AND SEMIOFFICIAL TESTS WITH RESPECT TO VARIABILITY IN PERCENTAGE OF FAT

TABLE 5.—SEVEN-DAY TEST: VARIABILITY IN FAT PERCENTAGE

Class interval; fat test, *percent*	Frequency	Average deviation	F(AD)	F(AD)²
2.21—2.40	0	0	0	0
2.41—2.60	4	-6	-24	144
2.61—2.80	22	-5	-110	550
2.80—3.00	76	-4	-304	1 216
3.01—3.20	119	-3	-357	1 071
3.21—3.40	178	-2	-356	712
3.41—3.60	217	-1	-217 -1 368	217
3.705 3.61—3.80	223	0	0	0
.2 3.81—4.00	161	1	161	161
4.01—4.20	118	2	236	472
4.21—4.40	80	3	240	720
4.41—4.60	33	4	132	528
4.61—4.80	26	5	130	650
4.81—5.00	13	6	78	468
5.01—5.20	5	7	35	245
5.21—5.40	8	8	64	512
5.41—5.60	4	9	36	324
5.61—5.80	3	10	30	300
5.81—6.00	4	11	44	484
6.01—6.20	0	12	0	0
6.21—6.40	0	13	0	0
6.41—6.60	1	14	14 +1 200	196
	1 295		- 168	8 970

Mean: 3.679 ± .010
Standard deviation: 0.5256 ± .0069
Coefficient of variability: 14.29 ± .18

SEMIOFFICIAL TEST

The calculation of the mean, the standard deviation, and the coefficient of variability for the semiofficial test furnishes an added opportunity for comparison. Table 6 shows the variability in percentage of fat for the semiofficial test.

The mean, or average percentage of fat, for the semiofficial period is 3.43 ± .006 percent. It is true that this average test is based on a rather selected group of cows; but the probable error (± .006) indicates that this group of 1,295 is adequate to determine a reliable average percentage of fat for the class of cows making semiofficial tests. The standard deviation of .317 ± .004 indicates that there is variability, but this variability is not so great as that found in the case of the seven-day test, the coefficient of variability being 9.22 ± .12.

In fat percentage the seven-day test is more variable than the semiofficial, the difference between the two tests being quite significant. This fact is of importance to the breeder who is forced to make selections from cows with seven-day records when he desires to breed up a herd in which the individuals have a higher percentage of fat in their milk for longer periods.

TABLE 6.—SEMIOFFICIAL TEST: VARIABILITY IN FAT PERCENTAGE

	Class interval; fat test, *percent*	Frequency	Average deviation	F(AD)		F(AD)^2
	2.21—2.40	1	-5	-5		25
	2.41—2.60	2	-4	-8		32
	2.61—2.80	14	-3	-42		126
	2.81—3.00	65	-2	-130		260
	3.01—3.20	213	-1	-213	-398	213
3.305	3.21—3.40	333	0	0		0
.2	3.41—3.60	329	1	329		329
	3.61—3.80	205	2	410		820
	3.81—4.00	78	3	234		702
	4.01—4.20	29	4	116		464
	4.21—4.40	15	5	75		375
	4.41—4.60	10	6	60		360
	4.61—4.80	0	7	0		0
	4.81—5.00	1	8	8	+1 232	64
		1 295			+ 834	3 770

Mean: 3.434 ± .006
Standard deviation: .3166 ± .004
Coefficient of variability: 9.22 ± .12

COMPARISON OF SEVEN- AND THIRTY-DAY TESTS

Many breeders are continuing their cows on official test for a thirty-day period. Naturally they are interested in knowing how it compares with the seven-day test. Table 7 and Fig. 5 show the relation between the seven-day and the thirty-day tests with respect to fat percentage.

TABLE 7.—COMPARISON OF SEVEN- AND THIRTY-DAY TESTS

Seven-day test			Frequency	Thirty-day test		
Milk production	Fat test	Fat production		Milk production	Fat test	Fat production
lbs.	*percent*	*lbs.*		*lbs.*	*percent*	*lbs.*
246.8	3.41	8.415	4	1 021.8	3.32	33.907
330.2	3.29	10.853	74	1 367.3	3.19	44.362
394.5	3.45	13.623	216	1 640.9	3.33	54.691
465.7	3.59	16.702	372	1 937.5	3.45	66.762
528.3	3.66	19.692	349	2 238.0	3.52	78.578
580.6	4.05	23.534	375	2 445.0	3.80	92.997

In this comparison between seven- and thirty-day tests, the records are arranged in groups according to seven-day production. With this arrangement there may be a tendency for the thirty-day test to regress toward the mean fat percentage for cows in general, but when it is considered that in almost every case the seven-day test forms a part of the thirty-day period, it is apparent that the tendency to regress must be slight.

The curves in Fig. 5 show that there is a uniform difference between these two tests with respect to the percentage of fat found in the milk. This comparison, based on an aggregate of 1,390 individual records, shows the seven-day test to have the higher percentage of fat. The difference in fat percentage between the tests is greatest in the case of high production. In low production the variation is .1 percent of fat; in high production, .25 of fat; making a difference of .15 percent between the extremes.

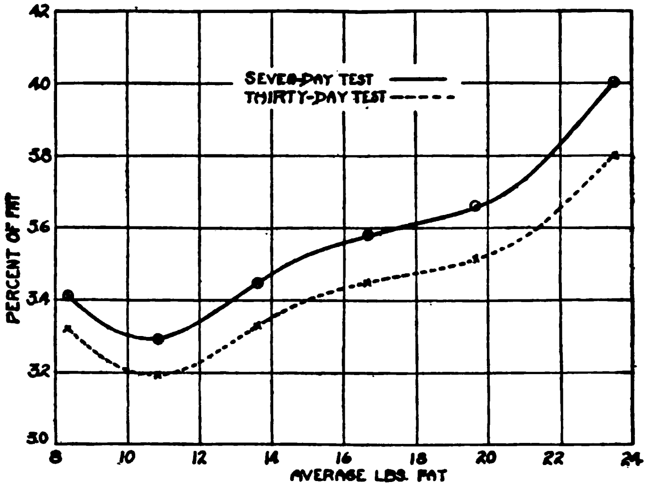

FIG. 5.—COMPARISON OF SEVEN-DAY AND THIRTY-DAY TESTS WITH RESPECT TO PERCENTAGE OF FAT

The drop in the curve in low production may be due to the fact that only four individual records are included in the averages which constitute the first group. Generally speaking, this number of records would be insufficient to establish dependable results.

COMPARISON OF THE SEVEN-DAY TEST AND THE SEVEN-DAY TEST EIGHT MONTHS AFTER CALVING

The seven-day test eight months after calving has evidently been little favored by breeders of Holstein-Friesian cattle, as only 209 tests were available for comparison prior to May 1, 1913. Table 8 shows the average fat percentage of the various groups for the original seven-day test when arranged according to amount of fat production, and Table 9 shows the same for the seven-day test eight months after calving. For graphic presentation, see Figs. 6 and 7.

TABLE 8.—ORIGINAL SEVEN-DAY TEST: RELATION BETWEEN FAT PRODUCTION AND FAT TEST

Class interval; fat production	Frequency	Milk production	Fat test	Fat production
lbs.		*lbs.*	*percent*	*lbs.*
Under 9.00	4	261.1	3.15	8.236
9.01—12.00	32	316.7	3.38	10.698
12.01—15.00	55	383.7	3.48	13.366
15.01—18.00	58	450.0	3.67	16.531
18.01—21.00	39	515.8	3.76	19.379
21.01 and over	21	593.8	4.08	24.246

TABLE 9.—SEVEN-DAY TEST EIGHT MONTHS AFTER CALVING: RELATION BETWEEN FAT PRODUCTION AND FAT TEST

Class interval; fat production	Frequency	Milk production	Fat test	Fat production
lbs.		*lbs.*	*percent*	*lbs.*
Under 8.00	30	211.1	3.28	6.925
8.01—10.00	69	262.5	3.46	9.085
10.01—12.00	59	305.9	3.62	11.084
12.01—14.00	33	359.5	3.62	12.987
14.01—16.00	11	401.0	3.68	14.749
16.01—18.00	6	423.5	3.78	15.993
18.01 and over	1	492.1	4.31	21.195

From a study of these tables and curves it is evident that there is a slight difference between the two tests in low fat production; the seven-day test eight months after calving being slightly higher in fat percentage than the original seven-day test. In the case of those cows which averaged 10.698 pounds of fat for the original seven-day test, the average fat percentage was 3.38; whereas cows that averaged 9.085 pounds fat when tested for seven days eight months after calving, had an average fat percentage of 3.46.

In high average fat production the reverse is true, the original seven-day test having the higher fat percentage. Those cows which averaged 24.246 pounds of fat for the original seven-day test produced, on the average, milk testing 4.08 percent. On the other hand, cows producing an average of 15.993 pounds of fat in the seven-day test eight months after calving, produced milk which on the average tested but 3.78 percent; there being a greater difference between the two tests in the percentages representing high average fat production than in the percentages representing low average fat production.

In this comparison, it must be borne in mind that a relatively small number of records are involved, and therefore that too much significance should not be attached to the results.

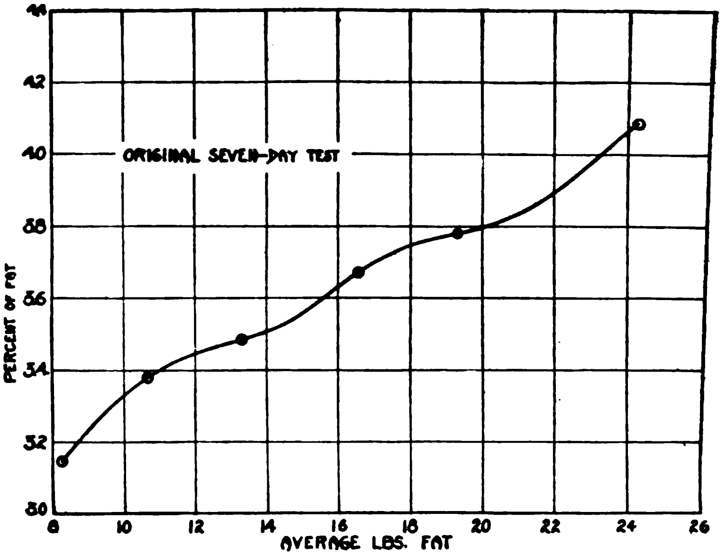

FIG. 6.—ORIGINAL SEVEN-DAY TEST: RELATION BETWEEN AMOUNT OF FAT AND PERCENTAGE OF FAT

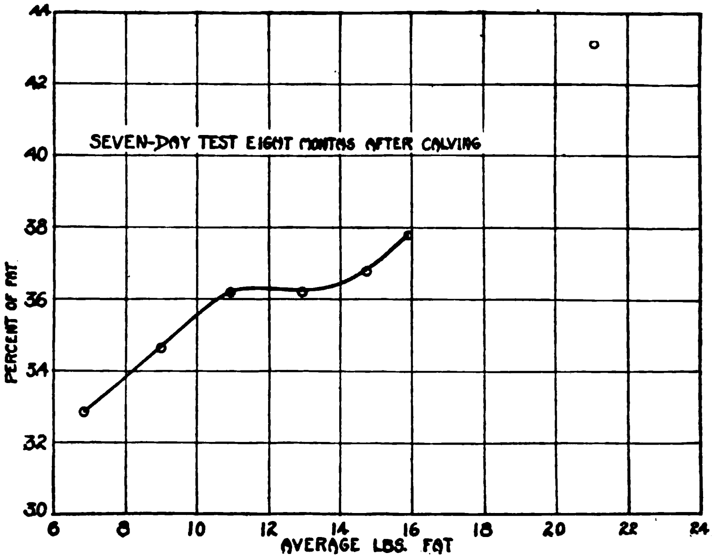

FIG. 7.—SEVEN-DAY TEST EIGHT MONTHS AFTER CALVING: RELATION BETWEEN AMOUNT OF FAT AND PERCENTAGE OF FAT

CORRELATION BETWEEN SEVEN-DAY AND SEMIOFFICIAL MILK TESTS

The measurement of correlation in this study has been confined to seven-day and semiofficial tests. The popularity and extensive use of the seven-day test makes it extremely desirable that the extent to which it may be used as an indication of semiofficial production, be determined. To measure the relationship which exists between these two tests, correlation tables have been used and coefficients have been determined.

TABLE 10.—CORRELATION BETWEEN SEVEN-DAY AND SEMIOFFICIAL MILK PRODUCTION

Semiofficial Milk Production

	Class interval; milk production, *lbs.*	7001—9000	9001—11000	11001—13000	13001—15000	15001—17000	17001—19000	19001—21000	21001—23000	23001—25000	25001—27000	27001—29000	29001—31000	Total
Seven-Day Milk Production	201—250	7	6	4	..	..	..	..	..	..	..	..	..	17
	251—300	11	33	34	13	1	..	..	..	..	..	..	..	92
	301—350	6	35	73	43	14	2	1	..	..	..	..	..	174
	351—400	3	20	70	70	47	14	2	1	..	..	..	..	227
	401—450	1	8	45	80	82	39	14	3	1	1	..	..	274
	451—500	..	4	31	51	46	47	17	6	1	..	..	..	203
	501—550	..	1	8	22	33	48	27	16	3	..	..	..	158
	551—600	..	..	3	5	23	25	17	11	1	..	1	1	87
	601—650	..	..	..	2	4	7	8	10	6	4	1	..	42
	651—700	..	..	..	..	1	2	1	2	2	..	2	1	11
	701—750	..	..	..	..	..	..	1	..	..	2	1	1	5
	751—800	..	..	..	..	..	..	..	1	2	..	1	..	4
	801—850	..	..	..	..	..	..	..	..	..	..	..	..	0
	851—900	..	..	..	..	..	..	..	..	..	..	..	..	0
	901—950	..	..	..	..	..	..	..	..	..	..	1	..	1
	Total.......	28	107	268	286	251	184	88	50	16	7	7	3	1 295

Table 10 shows the distributions from which the coefficient of correlation for the seven-day and the semiofficial milk production records has been calculated. A study of the results shows that there is a coefficient of correlation of .702 ± .01 between the seven-day and the semiofficial tests. The correlation .702 is for certain purposes a high degree of correlation, but it is not a high degree of correlation between two measurements of the same thing. That is to say, we are here concerned with two methods of measuring milk production of the same cow, and in order that each of them may be an effective measure of this production, they ought to be more closely correlated.

CORRELATION BETWEEN SEVEN-DAY AND SEMIOFFICIAL FAT PRODUCTION

In a similar way the coefficient of correlation between seven-day and semiofficial fat production has been determined. Table 11 gives the distribution from which this correlation has been calculated. From this table we find that the coefficient of correlation of fat production between the seven-day and the semiofficial tests is .703 ± .01, practically the same as that found for milk production; but, as in the case of milk production, altho it is a high correlation for certain purposes. it is not so regarded in this instance since the two tests are supposed to measure the same thing.

TABLE 11.—CORRELATION BETWEEN SEMIOFFICIAL AND SEVEN-DAY FAT PRODUCTION

Semiofficial Fat Production

Seven-Day Fat Production

Class interval; fat production, *lbs.*	251—225	326—400	401—475	476—550	551—625	626—700	701—775	776—850	851—925	926—1000	1001—1075	1076—1150	Total
7.01— 9.00	16	9	6	..	..	..	..	..	..	..	..	..	31
9.01—11.00	14	61	33	6	1	..	..	..	..	..	..	..	115
11.01—13.00	5	63	71	41	9	..	1	..	..	..	..	..	190
13.01—15.00	3	42	78	80	29	6	..	..	..	..	..	..	238
15.01—17.00	..	15	64	78	57	24	10	1	..	..	..	..	249
17.01—19.00	..	8	37	51	55	45	12	3	1	..	..	..	212
19.01—21.00	..	1	9	24	36	32	16	2	1	1	..	..	122
21.01—23.00	..	1	5	14	17	16	11	5	4	..	..	..	73
23.01—25.00	..	..	2	6	6	8	5	7	4	5	1	..	44
25.01—27.00	..	..	..	1	1	2	1	4	3	2	..	..	14
27.01—29.00	..	..	..	..	1	..	1	..	..	1	..	..	3
29.01—31.00	..	..	..	..	..	..	..	1	1	..	1	1	4
Total....	38	200	305	301	212	133	57	23	14	9	2	1	1295

From this study of correlation it would seem that it makes little difference whether one considers milk production or fat production, since the coefficients of correlation in both cases are almost the same. It further follows that since the correlation between seven-day and semiofficial tests is not high, it is not safe to attempt to use the seven-day as a criterion by which to judge semiofficial production.

CONCLUSIONS

From the data presented the following conclusions seem warranted. Of course, since they are based on the average of a large number of records, it must be remembered that they do not necessarily apply to individual cases.

1. The semiofficial test represents fairly accurately the producing ability of cows.

2. There is a greater difference in fat percentage between low and high fat production shown by the seven-day test than by the semiofficial test.

3. There is a greater tendency for high fat percentage to accompany high fat production in the seven-day test than in the semiofficial test.

4. The variability in fat percentage is greater for the seven-day test than for the semiofficial test. In fact the difference between these two tests is quite significant.

5. The seven-day test shows a higher percentage of fat than the thirty-day test. The difference is most marked in high production.

6. The limited number of records available for comparison indicate that the seven-day test eight months after calving carries a higher fat percentage in low fat production and a lower fat percentage in high fat production than the seven-day test.

7. The correlation between seven-day and semiofficial tests is not high either in milk or in fat production, when it is considered that they are measurements of the same thing.

8. The data presented in this study indicate that the seven-day test is not a satisfactory criterion by which to judge semiofficial production.

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BULLETIN No. 216

THE COST OF MILK PRODUCTION
COMPUTED ON THE YEAR BASIS

By F. A. PEARSON

URBANA, ILLINOIS, APRIL, 1919

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Summary of Bulletin No. 216

Introduction.—In studies pertaining to the cost of producing milk, a clear distinction must be made between milk produced for city trade and that produced for manufacturing purposes. The present study is confined to milk produced for direct consumption by the city trade. Page 343

Bases of Calculation.—There are three bases upon which the cost of milk production may be calculated; namely, the farm, the herd, and the cow. Page 344

Source of Data.—The data for the present study were obtained in the fluid milk district tributary to Chicago. Page 345

The Farm as the Unit.—Calculations based upon total farm receipts and disbursements do not present an adequate method for determining the cost of milk production, as the milk receipts even in an intensive dairy district often represent little more than half the gross farm income. Page 345

The Dairy Herd as the Unit.—With the herd as the basis of calculation, the aggregate value of 2.42 hours of man labor, 44 pounds of grain, 50 pounds of hay, 188 pounds of silage, and 39 pounds of other roughage approximately equaled in the present study, the net year cost of producing one hundred pounds of milk. Page 346

Prices of whole milk, however, cannot be constant thruout the year. A more or less satisfactory method for apportioning costs among the various months of the year is to use as a basis the percentage spread in the price paid for milk in the past. Page 356

The Cow as the Unit.—With the cow as the basis for calculating the cost of milk production, only the expense of maintaining the mature cows and bulls and the returns from them are involved. In the present study the net cost of producing one hundred pounds of milk on this basis was found to approximate the value of 35 pounds of grain, 36 pounds of hay, 140 pounds of silage, 29 pounds of other roughage, and 2.36 hours of labor; plus 25.6 percent. Page 357

Conclusions Page 364

Acknowledgment

Credit for the initiation of the studies of which this bulletin is a part, is due W. J. Fraser, Professor of Dairy Farming. His interest having been strongly drawn to the economic side of dairy farming, he early became convinced of the need of accurate studies in the cost of milk production, and in 1912 Mr. R. E. Brand was placed in charge and Mr. Pearson was secured to assist in these investigations. Since 1914 Mr. Pearson has been in charge. The present publication is the first resulting from this series of investigations.

Recognition should also be given Messrs. Frank Turner and H. K. Rulison for their conscientious application in the collection of the data for the cow and herd cost of milk production and for their constructive suggestions.

THE COST OF MILK PRODUCTION

COMPUTED ON THE YEAR BASIS

By F. A. PEARSON, Associate in Dairy Husbandry

INTRODUCTION

This bulletin reports the results of investigations into the cost of producing whole milk for city consumption, with 56 percent of the total produced during the winter months. It has no relation to the cost of producing summer milk primarily for buttermaking or to the cost of the surplus from general farming.

Altho the business of dairying appears relatively simple, it is in reality one of the most complicated types of American farming, and the problems encountered in attempting to ascertain the actual cost of production are difficult to solve. Much confusion has arisen from the fact that the difference in the cost of producing milk for city trade and producing it for manufacturing purposes has not been sufficiently recognized, and also from the fact that the different methods of computation used have made impossible the accurate comparison of the studies of different investigators.

Milk produced for urban consumption usually sells for more than it is worth for manufacturing purposes. Milk used for manufacturing purposes may be produced far from market, on pasture, which is the cheapest feed, and the finished product may be stored for winter use. Owing to the fact that whole milk is bulky and perishable, it must be produced relatively near the cities, where feeds are more expensive than in districts more remote. Furthermore, a larger proportion must be produced in the winter months than is the case with milk for manufacturing purposes. This also leads to more expensive production, since feeds are more expensive in the winter than in the summer months.

The greater part of the dairy products sold from the farm are used for manufacturing purposes rather than for direct consumption in the form of whole milk by the urban population. The dairy products used for manufacturing purposes are usually produced from small herds where dairying is a side issue to the other farm activities.

The production of milk for direct consumption is generally restricted to the more or less intensive dairying districts adjacent to the larger cities and forms the greater proportion of the total farm business.

Since Chicago is the largest urban center within the state and the second largest milk-consuming city of the country, it was deemed advisable to make certain detailed, cost-accounting studies pertaining to the production of milk in the surrounding dairy districts.

Most of the data thus far published have been expressed in terms of dollars and cents. As values are constantly changing, much of the work has not fulfilled its original purpose. In order, if possible, to eliminate the restrictions placed upon a study by fluctuating values, it was thought best to express the results of this investigation in terms of commodities whenever possible.

BASES OF CALCULATION

There are at least three bases upon which the cost of producing milk may be calculated: namely, the farm, the herd, and the cow. From the data secured for the present study it is possible to calculate costs from each of these various points of view.

By "farm cost" of milk production is meant the cost obtained by a method in which all farm receipts other than those from milk are deducted from the total farm expenses, leaving the remaining expenses to represent the cost of milk production. In case the receipts other than those from milk are almost negligible, this appears to be a satisfactory method; but the fact is that under the conditions of dairy farming in Illinois there are large receipts derived from sources other than milk. To use this "farm cost" method would in some cases be no more legitimate than for a railroad to find the cost of hauling passengers by deducting from the total expense of operating the railroads all receipts other than those for hauling passengers.

By "herd cost" of milk production is meant the cost obtained by a method in which the herd is made the basis of calculation and the cattle raising that accompanies the dairying is included in the cost accounting. One objection to this method is that the amount of feed which goes into milk production cannot be ascertained separately from that which goes into growing stock. As the value of the young stock tends in general to increase rapidly with age and the milking stock in general depreciates with age, the aggregate amount of appreciation will depend upon the ratio of the number of young stock to milch cows.

By "cow cost" of milk production is meant the cost obtained by a method in which the cow is the unit and credit is given for the value of the calves when dropped but the raising of the young stock is made a separate part of the business. The depreciation in the value of the milch cows becomes an expense of production.

One advantage of the cow cost is that it permits a comparison of results secured on different farms in the same or in different regions, or of the same farms or different farms in different years. The disadvantage of the herd cost lies in the fact that the amount of young stock kept varies, and comparisons are therefore difficult to make.

SOURCE OF DATA

The data presented showing the *farm cost* of milk production were secured in several townships in Kane and McHenry counties in 1911-12, and are based on the records of 680 typical dairy farms having a total of 19,802 cows producing for sale 104,516,900 pounds of milk. The average amount of milk sold per cow was 5,279 pounds. Of this, 57 percent was produced during the six winter months and 43 percent during the six summer months.

The data for *herd cost* were secured from 36 farms located in the fluid milk district tributary to Chicago. They do not involve any of the farms from which the data for the study of the farm cost were secured. The 36 farms had a total of 873 cows producing during the fiscal years 1914-15 and 1915-16, 5,683,992 pounds of milk containing 205,415 pounds of fat. The average milk sold per cow during the period was 6,511 pounds. This milk contained 235 pounds of fat, testing 3.61 percent. Fifty-six percent was produced during the six winter months and 44 percent during the remainder of the year.

The data for *cow cost* were secured from 16 of the farms from which the data concerning herd cost were obtained. These 16 farms had a total of 428 cows producing, during the years 1914-15 and 1915-16, 2,924,164 pounds of milk containing 104,144 pounds of fat. The cows produced on an average 6,832 pounds of milk and 243 pounds of fat. The average percentage of butter fat in the milk was 3.56. Fifty-six percent of the milk was produced in the six winter months and 44 percent in the six summer months.

THE FARM AS THE UNIT

Many persons insist that the farmer should have but one profit in dairy farming, and that the farm is the real unit on which the cost of milk production should be calculated. The farmer's business, however, is more complicated than is generally realized, and, altho not so large as many urban industries it is often more complex. The hog industry, the poultry industry, the dairy industry, and the individual crop industries are all separate and distinct parts of farm administration, and each may properly show a profit.

Using the data secured from the 680 dairy farms in Kane and McHenry counties, it is possible to determine the approximate farm cost of the milk which they produced. Table 1 shows this method of determining the cost of milk production.

TABLE 1.—THE FARM COST OF MILK PRODUCTION

As Secured from 680 Dairy Farms in Kane and McHenry Counties, Having a Total of 19,802 Cows Producing 1,045,169 Hundredweight of Milk: 1911-12

Items of expense and return	Amount	Per farm	Per cwt.
Total cash outlay, depreciation, and unpaid labor	$1 692 675	$2 489	$1.62
Interest on operating capital at 5 percent	132 457	195	.13
[1]Rent of land and buildings	380 316	559	.36
[2]Farmer's labor	408 000	600	.39
Total expense	$2 613 448	$3 843	$2.50
[3]Receipts other than for milk	1 120 202	1 647	1.07
Farm cost of production	$1 493 246	$2 196	$1.43

[1] The rent charged is the current rate paid for cash rented land.

[2] The farmers' labor is estimated at $600, which is the equivalent of hired men's wages.

[3] The receipts other than those for milk include those from crops and live stock sold, increase in value of inventory, and receipts for miscellaneous products.

The cost of production, as shown by this method of calculation, was $1,493,246 for the community, $2,196 per farm, and $1.43 per hundredweight of milk. The cash received for this milk totaled $1,664,931 for the community; $2,448 per farm; and $1.60 per hundredweight.

If the farms studied sold nothing but milk, the farm cost might be an accurate method of determining the cost of producing the milk. But according to this method, the farmer would, for example, make no profit on his hogs in a good year and suffer no loss on his corn crop if the community suffered from a drouth, for all losses or gains from the various enterprises would be expressed in terms of milk. On farms with a variety of income it would be just as consistent to analyze the cost of egg production in this way as to use it to determine the cost of milk production. The farms studied were in a very intensive dairy district, and yet only 58 percent of the receipts were derived from the sale of milk.

THE DAIRY HERD AS THE UNIT

When the herd is used as the unit for studying the cost of milk production, the expense of rearing young stock is included in the cost. The total expense of maintaining the herd involves eight items: feed, man labor, interest on live stock, horse labor, use of dairy equipment, use of buildings, and miscellaneous charges. The total credits to the herd involve receipts from milk sold, milk consumed by the family, increase in stock, manure, and miscellaneous receipts.

EXPENSES

FEED

On the thirty-six farms studied from the standpoint of the herd cost of milk production, feed constituted about two-thirds (66.05 percent) of the total expense of maintaining the herd. In the following tables the farm-raised feeds are charged to the dairy herd at prevailing farm values, while purchased feeds are charged at the purchase

TABLE 2.—AMOUNT AND VALUE OF GRAIN FED TO 873 COWS, 35 BULLS, AND 225 YOUNG STOCK IN THE PRODUCTION OF 5,683,992 POUNDS OF MILK CONTAINING 205,415 POUNDS OF FAT

Grain	Value	Weight in pounds	Value per cwt.	Value per cwt. of milk	Amount fed per cwt. of milk, in pounds
Corn	$7 799.96	817 777	$0.95	$0.1373	14.3874
Malt	5 029.65	368 284	1.36	.0885	6.4793
Bran	3 206.29	264 664	1.21	.0564	4.6563
Oats	2 812.05	222 596	1.26	.0495	3.9162
Gluten	2 350.04	157 432	1.49	.0413	2.7697
Ajax	1 858.35	109 344	1.70	.0327	1.9237
Cottonseed meal	1 495.69	96 759	1.55	.0263	1.7023
Barley	1 150.92	79 194	1.45	.0203	1.3933
Oil meal	779.59	44 775	1.74	.0137	.7877
Victor	674.15	47 489	1.42	.0119	.8355
White Diamond	665.45	47 700	1.40	.0117	.8392
Middlings	547.37	43 110	1.27	.0096	.7584
Dairy feed	467.78	32 600	1.43	.0082	.5735
R. K. D.	443.45	31 840	1.39	.0078	.5602
Hominy	340.87	25 290	1.35	.0060	.4449
Sugar feed	278.63	20 475	1.36	.0049	.3602
Calf meal	192.91	5 010	3.85	.0034	.0881
Germ meal	179.99	12 000	1.50	.0032	.2111
Empire	124.62	11 725	1.06	.0022	.2063
Unicorn	104.20	5 900	1.77	.0018	.1038
Shumacker	82.15	5 600	1.47	.0014	.0985
Rye	62.25	4 980	1.25	.0011	.0876
Climax	44.50	3 600	1.24	.0008	.0633
Akermane	40.30	2 660	1.52	.0007	.0468
Buckwheat middlings	39.72	4 965	.80	.0007	.0874
Tip Top	36.40	3 000	1.21	.0006	.0528
Chicago	34.50	3 375	1.02	.0006	.0594
Oat meal	17.45	670	2.60	.0003	.0118
Rye bran	16.75	1 275	1.31	.0003	.0224
Sucrene	14.40	800	1.80	.0003	.0141
Purina	13.50	1 200	1.12	.0002	.0211
H B	13.00	1 000	1.30	.0002	.0176
Molasses	9.50	675	1.41	.0002	.0119
B K	9.60	600	1.60	.0002	.0106
Sherwood	9.09	625	1.45	.0002	.0110
Cowpeas	4.40	440	1.00	.0001	.0077
Special	2.70	200	1.35	.0001	.0035
Blood meal	1.20	80	1.50	.00002	.0014
Oat bran	.73	100	.73	.00001	.0018
Total	$30 954.10	2 479 809	$1.248	$0.54473	43.6279

price. The labor of delivering these feeds to the farm appears under the items horse labor and man labor. The pasture is charged to the stock at the prevailing cash rates in the districts studied.

Grain.—The 873 cows and 148 other cattle units[1] involved in the production of the milk on these farms consumed 2,479,809 pounds of grain valued at $30,954.10. This grain represents in value more than one-third (36.6 percent) of the total feed given to the herd.

The kinds and amounts of grain fed are shown in Table 2. Of the total feeds classified as grain, the purchased feeds represent in value about three-fifths (61.8 percent) and the farm-raised feeds about two-fifths (38.2 percent).

The Illinois dairyman feeds more farm-raised grains than the eastern dairyman. A. L. Thompson[2] reports that 98 percent of the value of grains fed to cows on 174 farms in New York in 1912 was purchased and 2 percent farm raised. In Illinois corn is the most important grain, either raised or purchased, which is fed to dairy cows.

Hay.—In Table 3 are presented the amounts and weights of the various hays fed to the dairy herds. This class of feed represents in value about one-fifth (22.1 percent) of the total feed. Alfalfa, clover, timothy, and mixed hay formed the major portion of the feeds classified as hay.

The consumption of hay per hundredweight of milk was 50.16 pounds. This hay is valued at 65.6 cents per hundredweight, which leads to a cost of 33 cents for hay per hundredweight of milk produced.

TABLE 3.—AMOUNT AND VALUE OF HAY USED IN THE PRODUCTION OF 5,683,992 POUNDS OF MILK (ETC.)

Hay	Value	Weight in pounds	Value per cwt.	Value per cwt. of milk	Amount fed per cwt. of milk, in pounds
Alfalfa	$10 687.43	1 545 095	$0.69	$0.1879	27.1833
Clover hay	2 885.49	479 300	.60	.0508	8.4324
Timothy hay	2 445.60	355 145	.69	.0430	6.2482
Mixed hay	2 444.38	411 725	.59	.0430	7.2436
Millet hay	66.00	16 000	.41	.0012	.2815
Barley hay	32.00	8 000	.40	.0006	.1407
Oat hay	24.00	4 000	.60	.0004	.0704
Oat and pea hay	60.00	10 000	.60	.0011	.1759
Pea hay	30.00	6 500	.46	.0005	.1144
Wild hay	38.00	15 400	.25	.0007	.2709
Total	$18 712.90	2 851 165	$0.656	$0.3292	50.1613

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[1] One cow, one bull, or two head of young stock are considered a cattle unit. Two hundred and twenty-five young stock and 35 bulls are equivalent to 148 cattle units.

[2] Thompson, A. L. Cost of Producing Milk on 174 Farms in Delaware County, New York. Agr. Exp. Sta., Cornell University. Bul. 364, page 124. 1915.

Succulent Feeds.—Silage, green corn, and hays which were cut and fed green are classified as succulent feeds. These feeds represent in value one-fourth (25.8 percent) of the total feeds used. In Table 4 are shown the amounts and values of these feeds.

TABLE 4.—AMOUNT AND VALUE OF SUCCULENT FEEDS USED IN THE PRODUCTION OF 5,683,992 POUNDS OF MILK (ETC.)

Succulent feed	Value	Weight in pounds	Value per cwt.	Value per cwt. of milk	Amount fed per cwt. of milk, in pounds
Silage.............	$20 836.84	9 940 800	$0.21	$0.3665	174.8911
Green alfalfa.......	60.00	20 000	.30	.0011	.3519
Wet hay..........	2.00	400	.50	.00004	.0070
Green oat hay.....	20.00	10 000	.20	.0004	.1759
Green corn........	929.00	712 600	.13	.0163	12.5370
Total...........	$21 847.84	10 683 800	$0.204	$0.38434	187.9629

Other Roughage.—In the present study it was difficult to distinguish between corn stalks and corn fodder used as bedding and that used as feed. Many farmers feed the cows corn stalks and fodder, and after the edible portion is consumed the remainder is pushed back under the cows for bedding. In Table 5 are presented the amounts and values of these commodities so far as it was possible to classify them.

TABLE 5.—AMOUNT AND VALUE OF "OTHER" ROUGHAGE USED IN THE PRODUCTION OF 5,683,992 POUNDS OF MILK (ETC.)

Roughage	Value	Weight	Value per cwt.	Value of feed per cwt. of milk	Amount fed per cwt. of milk, in pounds
Corn fodder.......	$3 642.21	1 478 430	$0.25	$0.0641	26.0100
Oat straw..........	1 344.27	636 370	.21	.0237	11.1958
Wheat straw.......	94.25	37 500	.25	.0017	.6597
Barley straw.......	77.75	33 000	.24	.0014	.5806
Clover straw.......	35.00	30 000	.12	.0006	.5278
Timothy straw.....	29.00	11 400	.25	.0005	.2006
Rye straw.........	10.00	4 000	.25	.0002	.0704
Shavings..........	6.00	10 000	.06	.0001	.1759
Total...........	$5 238.48	2 240 700	$0.234	$0.0923	39.4208

Pasture.—Pasture represents but 8 percent of the total value of the feed consumed by the thirty-six herds. Table 6 shows the various classes of pasture and the value of each.

The blue-grass pasture constituted 84.4 percent of the value of the total pasture. The other pastures classified as oat stubble, wheat stubble, barley stubble, and corn stalks represent largely gleanings and a little volunteer grass or new seedings. Timothy, alfalfa, clover,

TABLE 6.—VALUE OF PASTURE USED IN THE PRODUCTION OF 5,683,992 POUNDS OF MILK (ETC.)

Pasture	Value	Value per cwt. of milk
Blue grass	$5 738.06	$0.10095
Oat stubble	233.00	.00410
Clover	203.86	.00359
Corn stalk	174.80	.00308
Timothy	166.50	.00293
Alfalfa	129.80	.00228
Mixed hay	97.50	.00172
Wheat stubble	40.00	.00070
Barley stubble	12.00	.00021
Total	$6 795.52	$0.11956

and mixed-hay pastures usually come after the crops have been cut. Altho the pastures other than blue grass represent but 15.6 percent of the total value of all pasture, they are of considerable importance, for they come at different periods thruout the pasture season and enable the farmer to rotate his fields. These stubble fields and cut-over hay fields form excellent pasture for short periods when the blue grass is dried up.

Miscellaneous Feeds.—These represent in value less than 2 percent of the total feed. In Table 7 are shown the amount and value of each. The skim milk, which was purchased, was the most important item.

TABLE 7.—AMOUNT AND VALUE OF MISCELLANEOUS FEEDS USED IN THE PRODUCTION OF 5,683,992 POUNDS OF MILK (ETC.)

Feed	Value	Weight in pounds	Value per cwt.	Value per cwt. of milk	Amount fed per cwt. of milk, in pounds
Skim milk	$826.91	315 373	$0.26	$0.0145	5.5484
Wet malt	161.82	40 405	.40	.0028	.7109
Cottonseed hulls	16.21	5 650	.29	.0003	.0994
Total	$1 004.94	361 428	....	$0.0176	......

Feed Summary.—The total amounts and value of all feed and forage entering into the production of the milk from the thirty-six farms under discussion, are summarized in Table 8.

The total feed required to produce the 5,683,992 pounds of milk is valued at $84,553.78, or $1.49 per hundredweight of milk.

TABLE 8.—SUMMARY OF ALL FEEDS FED TO 873 COWS, 35 BULLS, AND 225 YOUNG STOCK IN THE PRODUCTION OF 5,683,992 POUNDS OF MILK CONTAINING 205,415 POUNDS OF FAT

Feed	Value	Weight in pounds	Value per cwt. of milk	Amount fed per cwt. of milk, in pounds
Grain	$30 954.10	2 479 809	$.5447	43.63
Succulent feeds	21 847.84	10 683 800	.3843	187.96
Hay	18 712.90	2 851 165	.3292	50.16
Other roughage	5 238.48	2 240 700	.0922	39.42
Pasture	6 795.52	....	.1196	.....
Skim milk	826.91	315 373	.0145	5.54
Other feeds	178.03	46 055	.0031	.81
Total	$84 553.78	....	$1.4876	.....

LABOR

Next to feed, man labor is the most expensive factor entering into the production of milk. It includes the time spent in milking, in feeding, cleaning out barns, hauling feed, hauling milk, etc. Horse labor includes the time spent in hauling milk and feed, etc.

Man labor and horse labor do not include labor required in the production of crops or in the maintenance of other live stock.

TABLE 9.—NUMBER OF HOURS AND VALUE OF LABOR USED IN THE PRODUCTION OF 5,683,992 POUNDS OF MILK (ETC.)

Kind of labor	Value	Number of hours	Rate per hour in cents	Value of labor per cwt. of milk	Hours of labor per cwt. of milk
Man	$21 750.12	137 792.25	15.7847	$0.3826	2.4240
Horse	4 408.79	28 225.00	15.6200	.0776	.4965

In the data presented (Table 9) man labor represents 17 percent of the total expense of producing milk and horse labor 3 percent. The average cost of man labor was 15.78 cents per hour, and 2.42 hours were required to produce one hundred pounds of milk. The average rate per hour for the horse labor was 15.6 cents, one-half hour of which was necessary in the production of one hundred pounds of milk.

EQUIPMENT

The dairy equipment includes milking machines, milk carts, pails, strainers, can scales, etc. The cost of the dairy equipment constituted less than 2 percent (1.27 percent) of the total expense of producing the milk, and amounted on the average to about 3 cents per hundredweight of milk.

Depreciation represents 54 percent of the total equipment cost, and about one-fifth (20.59 percent) of the value of the equipment

TABLE 10.—TOTAL COST OF DAIRY EQUIPMENT USED IN THE PRODUCTION OF 5,683,992 POUNDS OF MILK (ETC.)

Value of equipment at beginning of the period	$4 288.02	
New equipment	2 133.57	
Initial inventory and purchases		$6 421.59
Value of equipment at end of period	$5 150.76	
Equipment sold	388.10	
Final inventory and sales		5 538.86
Depreciation		$882.73
Repairs	$494.70	
Taxes	8.44	
Interest on average value of equipment ($4,719.35 at 5 percent)	235.96	739.10
Net cost of operation		$1 621.83

at the beginning of the period. Repairs constituted 30 percent of the equipment cost; interest, 15 percent; and taxes, less than one percent.

MISCELLANEOUS EXPENSES

The miscellaneous expenses include insurance, taxes on stock, grinding farm feeds, registration, testing fees, veterinary fees, breeding fees, commissions, coal, salt, acid, medicine, dehorning, fly protector, whitewash, etc. They amounted to a total of $4,876.04, or 8.6 cents per hundredweight of milk, and constituted 3.8 percent of the gross expense of milk production.

INTEREST ON VALUE OF LIVE STOCK

Interest includes the annual charge for the use of the capital in the form of live stock. The average inventory value in the present study was $124,836.82; at 5 percent, the interest charge is $6,241.84, or about 11 cents per hundredweight of milk.

BUILDINGS

The building charge includes insurance, depreciation, interest on capital invested, cash repairs, labor repairs, paint, rent for the water system, etc. The total charge for buildings usually constitutes from 8 to 10 percent of the value of the buildings and 5 percent of the net cost of milk production. In this study it amounted to $4,563.65, representing 3.6 percent of the total gross expense.

RETURNS TO THE DAIRY HERD

The returns to the dairy herd involve receipts from milk sold, milk used by the household, miscellaneous returns, and manure. All returns other than for milk are deducted from the gross expense.

MILK

The milk sold represents three-fourths (75.2 percent) of the total income from the dairy herd.

During the period of this study 5,527,069 pounds of milk were sold and 156,923 pounds were consumed by the household. The total value of the milk sold and that consumed by the family was $95,525.11. The average price received for all milk sold was $1.68 per hundredweight.

STOCK

In using the herd as the basis of calculation, it must be borne in mind that the increase in the value of the young stock may be greater or less than the depreciation in the value of the milking stock, according to the policy of the dairyman. If it proves to be greater, as was the case in this study, then the net increase in the aggregate value of all the stock appears as an item of income.

In Table 11 is shown the stock transactions during the period of the study. During the year, 13 cows died and 281 cows were sold. This represents an annual turnover of 32 percent. During the same period 116 cows were purchased and 180 heifers freshened. The total increase in the value of the stock ($18,231.73) constituted 14.73 per-

TABLE 11.—KINDS, NUMBER, AND VALUE OF STOCK USED IN THE PRODUCTION OF 5,683,992 POUNDS OF MILK (ETC.)

Kind of stock	Number	Total value
Cows and bulls at beginning of period	907	$88 901.00
Cows bought	116	11 218.04
Heifers freshened	180	14 520.00
Two-year-old heifers at beginning of period	185	13 390.00
One-year-old heifers at beginning of period	251	12 340.00
Calves at beginning of period	311	8 745.07
Heifers bought	27	1 657.20
Calves bought	19	265.00
Original stock plus acquirements	1 996	$151 036.31
Cows and bulls at end of period	909	$88 437.00
Cows and bulls sold during period	281	18 384.06
Heifers freshened in period	180	14 520.00
Two-year-old heifers at end of period	196	12 663.00
One-year-old heifers at end of period	268	14 692.00
Calves at end of period	293	10 505.57
Heifers sold	100	5 925.20
Calves sold	436	4 141.21
Final stock plus sales	2 663	$169 268.04
Net increase	667	$18 231.73

cent of the gross income from the dairy herds. In terms of milk, it amounted to approximately 32 cents per hundredweight.

It should be explained that the actual market value of the cows and bulls at the end of the period was $4,283 greater than shown in Table 11, but as this amount was the result of appreciation in the general price level and not to appreciation in the value of the cows themselves, the cows were inventoried at the end of the period at the values prevailing at the beginning of the period.

MANURE

The simplest method of calculating the value of the manure is to consider only the manure hauled from the barns to the fields. The total value of this manure, estimated at $1 per load, amounted to $9,440.10. The labor in hauling the manure is charged to the crops, and not to the stock. Manure dropped on pastures is not included in this valuation since ordinary pasture rentals of $1 to $2 per head per month assume the return of that amount of fertility.

MISCELLANEOUS CREDITS

Miscellaneous credits form a very small part of the total returns from the dairy herds. The major items are sacks, bull service, hides, beef, and hauling. The total returns under this heading amounted to only $572.27, which is but one cent per hundredweight of milk.

NET HERD COST

The summary of the important factors of expense and of returns not milk are presented in Table 12. Feed is the most important item, constituting two-thirds (66.05 percent) of the gross expense. The feed cost per cow was $96.85, or $1.49 per hundredweight of milk, and the labor, $24.91, or 38 cents per hundredweight of milk. Man labor constituted about one-sixth (16.99 percent) of the gross expense.

The total expenses other than man labor and feed, except pasture, aggregated $.5016 per hundredweight of milk (horse labor, $.0776; equipment, $.0285; interest, $.1098; buildings, $.0803; pasture, $.1196; and miscellaneous expense, $.0858). The total returns not milk (stock, $.3208; manure, $.1661; and miscellaneous returns, $.0100) aggregated $.4969 per hundredweight of milk, an amount approximately equal to the total expenses other than man labor and feed, except pasture. The net cost of producing milk on these farms is then roughly equal to the sum of the man labor and the total feed exclusive of pasture.

In Table 13 is presented a summary of the man labor and of the feed, except pasture, involved in the production of the 5,683,992 pounds of milk.

TABLE 12.—SUMMARY OF TOTAL EXPENSE AND OF RETURNS NOT MILK INVOLVED IN THE PRODUCTION OF 5,683,992 POUNDS OF MILK (ETC.)

	Total	Percent of total	Per cwt. of milk produced
EXPENSES			
Feed other than pasture	$77 758.26	60.74	$1.3679
Pasture	6 795.52	5.31	.1196
Man labor	21 750.12	16.99	.3827
Interest on herd	6 241.84	4.88	.1098
Miscellaneous	4 876.04	3.80	.0858
Horse labor	4 408.79	3.44	.0776
Buildings	4 563.65	3.57	.0803
Equipment	1 621.83	1.27	.0285
Total	$128 016.05	100.00	$2.2522
RETURNS NOT MILK			
Appreciation of stock	$18 231.73	......	$.3208
Manure	9 440.10	......	.1661
Miscellaneous	572.27	......	.0100
Total	$28 244.10	......	$.4969
NET YEARLY HERD COST	$99 771.95	......	$1.7553

TABLE 13.—AMOUNT AND VALUE OF MAN LABOR AND OF FEED, EXCEPT PASTURE, USED IN THE PRODUCTION OF 5,683,992 POUNDS OF MILK (ETC.)

	Value	Amount	Value per cwt. of milk	Amount per cwt. of milk
Man labor	$21 750.12	137 792.25 hrs.	$0.3826	2.42 hrs.
Grain	30 954.10	2 479 809.00 lbs.	.5447	43.63 lbs.
Silage	21 847.84	10 683 800.00 lbs.	.3843	187.96 lbs.
Hay	18 712.90	2 851 165.00 lbs.	.3292	50.16 lbs.
Other roughage	5 238.48	2 240 700.00 lbs.	.0922	39.42 lbs.
Miscellaneous feeds	1 004.94	361 428.00 lbs.	.0176	6.36 lbs.
Total	$99 508.38	....	$1.7506	....

Owing to the fact that values are constantly changing, it seems necessary that results be expressed in terms of commodities whenever possible. The items of feed and man labor are most easily expressed in this way: man labor in terms of hours, and feed, except pasture, in terms of pounds. Since the feeds listed as miscellaneous[1] form a relatively small proportion of the total feed used, they may be disregarded in forming a simple, practicable, and comparatively accurate method for arriving at the approximate cost of milk production. For practical purposes the following amounts of feed, forage, and man labor represent the complete net cost of producing one hundred pounds of milk, and their use as a general formula offers a simple basis for computing the approximate year cost of milk production:

---

[1] See Table 7.

Grain	44 pounds	Hay	50 pounds
Silage	188 pounds	Other roughage	39 pounds
Man labor	2.42 hours		

In using these items as a basis for calculating the expense of producing one hundred pounds of milk, it is assumed that as the prices of feeds and labor rise or fall the other items of expense and return fluctuate more or less in the same proportion. For instance, equipment, buildings, interest, pasture, and miscellaneous expenses fluctuate in proportion to the value of manure, the increase in stock, and miscellaneous returns. Altho there is probably no time when they fluctuate in exact unison, they keep close enough together for practical purposes of computation. It is also assumed that the amount fed was not far from that which was physiologically most efficient under the prevailing conditions.

This method operates as follows: Assuming the value of grain to be $55 per ton; hay, $10 per ton; silage, $6 per ton; and man labor, 25 cents per hour, we have:

Grain	44 lbs.	@ $55 per ton	= $1.21
Silage	188 lbs.	@ 6 per ton	= .56
Hay	50 lbs.	@ 10 per ton	= .25
Other roughage	39 lbs.	@ 6 per ton	= .12
Man labor	2.42 hours	@ 25c per hour	= .61

Yearly herd cost of milk per hundredweight............$2.75

SEASONAL VARIATIONS IN THE COST OF PRODUCTION

The application of current values to the hours of labor and pounds of grain produces a result termed the "year cost" of milk production, which does not represent the cost at any one season of the year. A more or less satisfactory method of distributing the year cost over the various months is to use the relative percentage variations in the prices paid for milk during the different months of the year at the market to which the milk was delivered. The buyers of milk desire a constant supply thruout the year, and it may be assumed, therefore, that prices have been adjusted to stimulate the production of the desired amount each month of the year. The percentage variation by months, of the average annual Chicago price[1] of milk for the ten years 1907-1916, was as follows:

Month	Percentage variation	Month	Percentage variation
January	119.0	July	83.7
February	114.3	August	94.2
March	106.5	September	96.7
April	94.2	October	109.2
May	73.2	November	118.3
June	70.6	December	120.3

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[1] Milk News.

It will be noticed that the December price is the highest, being 20.3 percent above the average price. The August price is 5.8 percent less than the average price. From December to June (the month of the lowest average) there is a variation of 49.7 percent.

If it is assumed that the year cost of milk production is $2.75 per hundredweight, as shown on page 346, and the percentage deviations shown above are applied, the cost for January would be found to be $3.27 per hundredweight ($2.75×1.19=$3.27); the cost for August, $2.59 per hundredweight ($2.75×.942=$2.59); etc.

The so-called monthly spread, monthly deviation, or monthly differential is based on the fact that a December price 20.3 percent above the average year price and a June price 29.4 percent less than the average year price, with the intervening months gradually approaching these extremes, produced in the past the desired volume of milk each month of the year, and therefore must have been somewhat commensurate with the cost.

THE COW AS THE UNIT

When the cow is made the basis for calculating the cost of milk production, the cost of rearing young stock to mature cows is eliminated. There are eight items of expense taken into consideration; namely, feed, man labor, depreciation, horse labor, interest on value of stock, buildings, miscellaneous, and dairy equipment, and they are of importance in the order named. There are three items of return other than milk; namely, manure, calves, and miscellaneous.

The data used for this study are a part of the data obtained for the study pertaining to herd cost, but since some of the latter do not permit of a separation of cow feed from young stock feed, it is impossible to include all in the cow cost study.

EXPENSES

FEED

In the cost of maintaining a cow, feed is the most important factor. The farm-raised feeds involved in this study are charged to the cows at the prevailing farm values and not at the cost of their production. Purchased feeds are charged at actual market values. The man labor and horse labor required to deliver these commodities to the farms are charged under the items man labor and horse labor.

Grain.—The value of the grain fed the 446 cattle units involved in the production of the 2,924,164 pounds of milk constituted 39 percent of the total value of the feed used.

About 40 percent of the total grains were farm-raised. Of these, the value of the corn represents somewhat less than two-fifths of the

TABLE 14.—AMOUNT AND VALUE OF GRAIN CONSUMED BY 428 COWS AND 18 BULLS (446 CATTLE UNITS) IN THE PRODUCTION OF 2,924,164 POUNDS OF MILK CONTAINING 104,144 POUNDS OF FAT

Grain	Value	Weight in pounds	Value per cwt. of milk	Amount per cwt. of milk, in pounds
Corn	$4 369.10	480 016	$0.1494	16.4154
Malt	2 113.47	158 463	.0723	5.4191
Bran	961.08	75 179	.0329	2.5710
Gluten	715.69	46 873	.0245	1.6030
Cottonseed meal	704.00	43 388	.0241	1.4838
Ajax	631.39	37 993	.0216	1.2993
White Diamond	592.42	42 465	.0203	1.4522
Oil meal	474.80	27 470	.0162	.9394
Barley	402.65	30 606	.0138	1.0467
Oats	345.56	25 989	.0118	.8888
Hominy	253.71	18 797	.0087	.6428
Middlings	115.20	8 091	.0039	.2767
Victor	44.48	3 308	.0015	.1131
Sugar feed	44.41	3 617	.0015	.1237
Buckwheat bran	32.92	4 115	.0011	.1407
Purina	13.50	1 200	.0005	.0410
Buckwheat middlings	9.60	600	.0003	.0205
Schumacker	9.09	625	.0003	.0214
Stock feed	9.00	200	.0003	.0068
Cottonseed hulls	7.48	2 607	.0003	.0892
Cowpeas	4.40	440	.0001	.0151
Molasses feed	2.39	111	.0001	.0038
Oat bran	.73	100	.0000	.0034
Total	$11 857.07	1 012 253	$0.4055	34.6169

value of the total grain feed. The value of the malt represents somewhat more than one-third of the value of the purchased grains. Thirty-five pounds of grain, costing 41 cents, were required to produce one hundred pounds of milk.

Succulent Feeds.—In Table 15 is shown the amount and value of the succulent feeds. The cost of these feeds constituted about one-fourth (25.9 percent) of the total cost of all feeds, and the cost of the silage represents more than nine-tenths of the total cost of the succulent feeds. Of the succulent feeds used per hundred pounds of milk produced, 9 pounds were green corn and 131 pounds were silage. The average cost of succulent feeds per hundredweight of milk produced was 27 cents.

TABLE 15.—AMOUNT AND VALUE OF SUCCULENT FEEDS USED IN THE PRODUCTION OF 2,924,164 POUNDS OF MILK (ETC.)

Succulent feed	Value	Weight in pounds	Value per cwt. of milk	Amount fed per cwt. of milk, in pounds
Silage	$7 580.16	3 831 452	$0.2592	131.0346
Green corn	385.00	265 000	.0132	9.0630
Total	$7 965.16	4 096 452	$0.2724	140.0976

Hay.—About one-fourth (22.2 percent) of the value of the total feeds used, was hay. The more important hays were alfalfa, clover, timothy, and mixed. About 36 pounds (35.7) were used in producing one hundred pounds of milk.

TABLE 16.—AMOUNT AND VALUE OF THE DIFFERENT KINDS OF HAY USED IN THE PRODUCTION OF 2,924,164 POUNDS OF MILK (ETC.)

Hay	Value	Weight in pounds	Value per cwt. of milk	Amount fed per cwt. of milk, in pounds
Alfalfa	$3 307.89	428 363	$0.1131	14.6491
Mixed	1 167.26	190 107	.0399	6.5012
Clover	1 141.82	214 895	.0391	7.3489
Timothy	1 087.32	176 881	.0372	6.0489
Oat and pea	85.43	15 623	.0029	.5343
Millet	28.57	9 524	.0010	.3257
Wild	20.80	9 000	.0007	.3078
Total	$6 839.09	1 044 393	$0.2339	35.7159

Other Roughage.—"Other" roughage constituted but 6.4 percent of the value of the total feed. In Table 17 are shown the amounts and values of these forages. Of the 29 pounds necessary to produce one hundred pounds of milk, 22 pounds were corn fodder and 7 pounds were straw. The total cost was 6.7 cents per hundred pounds of milk.

TABLE 17.—AMOUNT AND VALUE OF OTHER ROUGHAGE USED IN THE PRODUCTION OF 2,924,164 POUNDS OF MILK (ETC.)

Roughage	Value	Weight	Value per cwt. of milk	Amount fed per cwt. of milk, in pounds
Fodder	$1 499.97	650 763	$0.0513	22.2547
Straw	466.37	203 852	.0160	6.9713
Total	$1 966.34	854 615	$0.0673	29.2260

Pasture.—In Table 18 is shown the total value of each class of pasture used. Blue grass was by far the most important.

TABLE 18.—TOTAL VALUE OF PASTURE USED IN THE PRODUCTION OF 2,924,164 POUNDS OF MILK (ETC.)

Pasture	Value	Value per cwt. of milk
Oat stubble	$ 14.00	$.0005
Blue grass	1 750.33	.0599
Alfalfa	50.00	.0017
Clover	92.08	.0031
Cornstalk	61.45	.0021
Timothy	120.00	.0041
Total	$2 087.86	$.0714

Feed Summary.—The total feed involved represents over one-half (55.9 percent) the gross expense of producing the milk. In Table 19 is presented a summary of the amounts and values of the various feeds used. The total feed cost was $1.05 per hundred pounds of milk.

TABLE 19.—SUMMARY OF ALL FEEDS FED TO 428 COWS AND 18 BULLS (446 CATTLE UNITS) IN THE PRODUCTION OF 2,924,164 POUNDS OF MILK CONTAINING 104,144 POUNDS OF FAT

Feed	Value	Weight	Value per cwt. of milk	Amount fed per cwt. of milk, in pounds
Grain	$11 857.07	1 012 253	$.4055	34.6169
Succulent feeds	7 965.16	4 096 452	.2724	140.0976
Hay	6 839.09	1 044 393	.2339	35.7159
Other roughage	1 966.34	854 615	.0673	29.2260
Pasture	2 087.86	....	.0714	....
Total	$30 715.52	....	$1.0505	....

LABOR

Man labor and horse labor are important factors in milk production; in the present study they constituted nearly one-fourth (23.7 percent) of the gross expense. It will be seen from Table 20 that to produce the 2,924,164 pounds of milk, 69,098.25 hours of man labor were required. This is 2.36 hours (37 cents) per hundredweight of milk. One-half hour (.523) of horse labor was utilized in the production of one hundred pounds of milk.

TABLE 20.—AMOUNT AND VALUE OF LABOR USED IN THE PRODUCTION OF 2,924,164 POUNDS OF MILK (ETC.)

Kind of labor	Total value	Total hours	Value per cwt. of milk	Amount used per cwt. of milk, in pounds
Man labor	$10 821.97	69 098.25	$.3701	2.3630
Horse labor	2 207.65	15 289.75	.0755	.5229

EQUIPMENT

In Table 21 is shown the various items involved in the equipment cost. It will be seen that the net cost of equipment constitutes a relatively small portion of the total cost of milk production.

Of the total equipment cost, depreciation represents 57.7 percent; repairs, 20.7 percent; interest, 21.0 percent; and taxes, 0.6 percent.

BUILDINGS

The buildings necessary to house the 428 cows and 18 bulls constituted about 4 percent of the gross expense of producing the 2,924.164 pounds of milk.

TABLE 21.—COST OF DAIRY EQUIPMENT USED IN THE PRODUCTION OF 2,924,164 POUNDS OF MILK (ETC.)

Value of equipment at beginning of the period	$1 083.70	
New equipment	1 227.77	
Initial inventory and purchases		$2 311.47
Value of equipment at end of period	$1 871.40	
Equipment sold	236.75	
Final inventory and sales		2 108.15
Depreciation		$203.32
Repairs	$72.75	
Taxes	2.04	
Interest on average value of equipment ($1,477.52 at 5 percent)	73.88	148.67
Net cost of operation		$351.99

STOCK

In order to maintain milk production, it is necessary to continually change the milking stock. To maintain the herds on the farms studied at an average of 428 cows, 95 cows were sold, 45 cows were bought, and 66 heifers freshened. Eight cows which died during the time of the study represent about 2 percent of the average number of cows. The farmers aim to keep the cows as long as they are economical producers and try to dispose of them when they become unprofitable. The animals that were sold represent 22.2 percent of the total number involved. In other words, the average cow remained in the herd about 4.5 years.

TABLE 22.—NUMBER AND VALUE OF STOCK USED IN THE PRODUCTION OF 2,924,164 POUNDS OF MILK (ETC.)

	Number	Average value	Total value
Cows and bulls at beginning of period	443	$98.14	$43 476.00
Cows purchased	45	119.01	5 355.53
Heifers freshened	66	74.02	4 885.00
Total stock involved	554	$96.96	$53 716.53
Cows and bulls at end of period	451	$94.66	$42 692.00
Cows sold	95	67.85	6 445.48
Final stock plus sales	546	$90.00	$49 137.48
Depreciation	...	......	$4 579.05

INTEREST ON VALUE OF LIVE STOCK

The interest on the capital invested in live stock ($43,084.00) at 5 percent amounted to $2,154.20, or 7.37 cents per hundredweight of milk.

RETURNS NOT MILK

MANURE

Manure represents about one-seventh of the total income to the dairy. The amounts included in these calculations are those hauled from the barn; they do not include manure dropped on pasture.

CALVES

The 428 cows produced 363 calves, which number represents approximately 85 living calves for each one hundred cows. The casual observer would probably think that the cows should produce a larger percentage of living calves, but the failure of cows to breed and the losses from diseases, such as abortion, increase beyond the usual conception the expense of milk production.

MISCELLANEOUS RECEIPTS

The miscellaneous receipts include hides, $89.65; beef, $37.60; bull service, $6.00; feed for hogs following cows, $11.25; milk hauling, $54.50; and feed bags, $47.30. They amounted in total to less than one cent ($.0084) per hundredweight of milk.

NET COW COST

Table 23 presents a summary of all the factors of expense and of income except milk, involved in the production of 2,942,164 pounds of milk from 446 cattle units.

From the above table it is seen that the value of the feed not pasture ($0.9791 per hundredweight of milk) plus the value of man labor ($0.3701) constituted 79.58 percent of the net cost of producing the milk ($1.6953). In other words, the total value of the feed not pasture and the man labor falls short by 20.42 percent of representing the actual net cost of the milk. The reason for the lower proportion which feed and labor constitute by this method of calculation, as compared with the herd cost, lies in the elimination of the young stock from the records. It is of course an obvious fact that proportionately more feed would be required to produce one hundred pounds of milk when the feed given the young stock in the herd was included as a part of the cost of production, than when only the feed given the producing cows and bulls was included; and also, in a study confined to cow cost there is no appreciation in value of young stock to offset various other items of expense, as there is in a study in which the entire herd is included.

Table 24 shows in amounts as well as in value the man labor and feed except pasture involved in the production of the 2,924,164 pounds

TABLE 23.—SUMMARY OF ALL ITEMS OF EXPENSE AND OF RETURNS OTHER THAN MILK INVOLVED IN THE PRODUCTION OF 2,924,164 POUNDS OF MILK (ETC.)

Item	Amount	Percent of total	Per cwt. of milk
EXPENSE			
Feed not pasture	$28 627.66	52.2	$0.9791
Pasture	2 087.86	3.8	.0714
Man labor	10 821.97	19.7	.3701
Depreciation in value of stock	4 579.05	8.3	.1566
Horse labor	2 207.65	4.0	.0755
Interest on value of stock	2 154.20	3.9	.0737
Buildings	2 128.89	3.9	.0728
Miscellaneous	1 889.77	3.5	.0646
Equipment	351.99	.7	.0120
Total	$54 849.04	100.0	$1.8758
RETURNS NOT MILK			
Manure	$3 943.88	.....	$.1349
Calves	1 089.00	.....	.0372
Miscellaneous	246.30	.....	.0084
Total	$5 279.18	.....	$.1805
NET YEARLY COW COST	$49 569.86	.....	$1.6953

TABLE 24.—AMOUNT AND VALUE OF MAN LABOR AND OF FEED, EXCEPT PASTURE, USED IN THE PRODUCTION OF 2,924,164 POUNDS OF MILK (ETC.)

Item	Value	Amount	Value per cwt. of milk	Amount per cwt. of milk
Man labor	$10 821.97	69 098.25 hrs.	$0.3701	2.3630 hrs.
Grain	11 857.07	1 012 253.00 lbs.	.4055	34.6169 lbs.
Silage	7 965.16	4 096 452.00 lbs.	.2724	140.0976 lbs.
Hay	6 839.09	1 044 393.00 lbs.	.2339	35.7159 lbs.
Other roughage	1 966.34	854 615.00 lbs.	.0673	29.2260 lbs.
Total	$39 449.63	....	$1.3492	....

of milk. On this basis the approximate cow cost of producing one hundred pounds of milk may be secured by adapting prevailing prices to the following quantities of feed and labor and dividing this amount by 79.58 percent or by adding 25.6 percent of the value:

Grain	35 pounds	Hay	36 pounds
Silage	140 pounds	Other roughage	29 pounds
Man labor	2.36 hours		

The use of these amounts presupposes that the prices of all items included change more or less in unison and also that the cost of each item not included fluctuates with some one of the items that is included: e. g., the cost of horse labor fluctuates with the price of feed; the depreciation of stock changes with the price of feed and labor; at the same time credits not milk, such as manure, change with the price of feeds. Altho these fluctuations never occur in exact unison, they are never very far apart. Following is an illustration of how the formula may be used:

Grain	35 lbs.	@ $55 per ton	= $0.96	
Silage	140 lbs.	@ 6 per ton	= .42	
Hay	36 lbs.	@ 10 per ton	= .18	
Other roughage	29 lbs.	@ 6 per ton	= .09	
Man labor	2.36 hours	@ 25c per hour	= .59	
				$2.24
Add 25.6 percent of $2.24				.57
Yearly cow cost of milk per hundredweight				$2.81

For a discussion concerning seasonal variation in cost, the reader is referred to page 356.

CONCLUSIONS

The cost of producing one hundred pounds of milk may be determined by computing either the cost of maintaining the entire herd or the cost of maintaining the producing stock alone.

With the herd as the basis, the approximate year cost may be ascertained by applying current prices to the following amounts of feed and labor:

Grain	44 pounds	Hay	50 pounds
Silage	188 pounds	Other roughage	39 pounds
Labor	2.42 hours		

With the milking stock as the basis, the approximate year cost may be ascertained by applying current prices to the following amounts of feed and labor and adding 25.6 percent to the value thus obtained:

Grain	35 pounds	Hay	36 pounds
Silage	140 pounds	Other roughage	29 pounds
Labor	2.36 hours		

Of course when studies pertaining to costs are restricted to a comparatively small number of farms supplying a given market, certain limitations are placed upon the data which must be taken into consideration when applying the results to individual farms or to other districts. For instance, if high production and superior skill reduce the amount of labor necessary on the better farms, average farm wages should not be used in determining the labor cost, but rather the wages of the superior class to which the data are applicable. The same is true for feeds. Due cognizance must also be given to the ratio of winter milk to summer milk, for the cost of producing the former is much the greater. In the present study the lower cost of production resulting from the fact that better farms were involved tends to counterbalance the higher cost of the large proportion of winter production, but it is impossible to say with exactness which factor exerts the greater influence.

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THE RIGHT TIME TO PLANT VEGETABLES

By J. W. LLOYD, Chief in Olericulture

Some people seem to think that all vegetables are alike in one respect at least; namely, that all may be planted at the same time. Furthermore, they apparently believe that this time may be whenever they feel the inclination or have a few hours they can spare from their regular duties. The result is that peas and lima beans, lettuce and cucumbers, cabbage and tomatoes, are all planted at the same time. As a matter of fact, when the weather is most favorable for the growth of peas, lettuce, and cabbage, it is entirely too cool for the proper development of the other crops named; and when it has become sufficiently warm for cucumbers and tomatoes, the best part of the growing season for lettuce and early cabbage is already past.

No farmer thinks of sowing oats and planting corn at the same time, because oats demand cool conditions, and corn thrives best in warm weather. There is as much difference between the temperature requirements of spinach and muskmelons as those of oats and corn. Each kind of vegetable thrives best under certain climatic conditions. When many kinds are grown in the same garden, the only way that each can be favored with the climatic conditions most suitable for it, is to adjust the time of planting to the requirements of each particular crop, so that it will have a chance to grow in the part of the season most favorable to its development. It is true that seasons vary, and some years the conditions are more favorable for the growth of a given crop than others. However, the gardener should always take the precaution to plant each crop at the most favorable time possible.

There are over fifty different kinds of vegetables grown in America, of which more than thirty are quite commonly grown in home gardens. While each crop demands certain conditions, these conditions are similar for a number of crops. This makes it possible to classify the vegetable crops into groups, the various members of which require essentially the same conditions of temperature and moisture, and hence should be planted at approximately the same time.

In the first place, vegetables are divided into *cool-season* and *warm-season* crops. The cool-season crops are not injured by light frosts and grow best in relatively cool weather. The warm-season crops are easily injured by frost and do not grow rapidly or develop properly except in warm weather.

The cool-season crops may be further classified into four groups:

(1) The first group consists of vegetables which demand cool weather thruout their entire period of growth, but which are able to complete their growth in so short a period that if the seed is planted in the open ground as early as the soil reaches workable condition in spring, the crop will be ready for harvesting before the heat of summer arrives. The following vegetables belong to this group: Leaf lettuce, garden cress, spinach, mustard, radishes, turnips, and peas. These should be planted as early as possible in the spring, the exact date depending on the earliness or lateness of the particular season. Some of these crops may also be grown in the fall, if there is sufficient rain or if means for artificial watering are available. In this case, they are planted after the hot weather of summer is over.

(2) There is another group of plants which require cool weather for their proper development, but which have so long a period of growth that in order that they may complete their development before the arrival of hot weather, they must be started under glass before the weather is suitable for outdoor planting, and then transplanted to the open ground as soon as conditions permit. Head lettuce, early cabbage, and early cauliflower belong to this group. Under normal conditions, these are transplanted about April 10 to 15 in central Illinois. The plants are grown from seed sown in hotbeds five or six weeks before the time of transplanting.

(3) Late cabbage, late cauliflower, Brussels sprouts, and celery are also crops which demand cool weather for their proper development. Under Illinois conditions the plants are started in seed beds before the heat of summer arrives, and later are transplanted to the field, where they are nursed along as well as possible thru the summer. They make their principal growth during the cool weather of autumn,

but must be started considerably in advance of that season to complete their growth before winter sets in. They make their best crops in seasons when the summers are cooler than normal, or in northern localities which are free from the intense heat characteristic of the corn belt. Late cauliflower and Brussels sprouts will not stand as much heat as late cabbage and celery, and are more uncertain crops except in localities where the summers are unusually cool. The commercial culture of all four of these crops is limited principally to northern localities. For home gardens in Illinois, except in the northern part of the state, they are rather unreliable crops.

(4) Another group of cool-season crops is composed of those which require cool weather at the start, but which are able to stand considerable heat and even drouth after they have once become fully established. This group includes beets, carrots, parsnips, parsley, salsify, horse-radish, Swiss chard, kale, collards, New Zealand spinach, onions, leeks, garlic, and potatoes. Under Illinois conditions these crops are normally planted as early in the spring as the ground can readily be worked. Some members of the group will stand harder frosts than others, and demand earlier planting. It is especially important that onions and potatoes be planted very early.

The warm-season crops may readily be classified into two groups: (1) those which have a sufficiently short period of growth to enable them to mature their crops before the frosts of fall, even tho the seed is not planted till after danger of spring frosts is over; and (2) those which require so long a season that the plants must be started under glass while the weather is still cool outside, and later transplanted to the open.

The first group includes beans (both string and lima), sweet corn, okra, cucumbers, muskmelons, watermelons, pumpkins, and squashes. Of these crops, string beans and sweet corn will start growth at somewhat lower temperatures than the others, and may be planted as early as May 1 in a normal season in central Illinois, while the others usually cannot be planted with safety until about two weeks later.

The warm-season crops requiring transplanting are tomatoes, eggplants, peppers, and sweet potatoes. Tomatoes and peppers will stand somewhat cooler weather than will eggplants and sweet potatoes, and in a normal season in central Illinois may be transplanted to the open ground about May 15. On the other hand it is usually unsafe to set out eggplants and sweet potatoes before June 1. The seed of tomatoes, peppers, and eggplants should be planted at least eight or ten weeks before time for setting out the plants. Good sweet-potato plants may be grown in four to five weeks from tubers properly handled.

No planting dates can be set for the various crops that will apply to all seasons or all localities. However, under ordinary conditions in central Illinois the following schedule will be a safe guide:

(1) Plant as early as the ground can be worked in the spring (usually between March 20 and April 1): leaf lettuce, garden cress, spinach, mustard, radishes, turnips, smooth-seeded peas, onions (both seed and sets), leeks, garlic, horse-radish, kale, potatoes.

(2) Plant about April 10 to 15: beets, carrots, parsnips, parsley, salsify, Swiss chard, collards, New Zealand spinach, wrinkled peas, cabbage, cauliflower.

(3) Plant about May 1: string beans, sweet corn.

(4) Plant about May 15: lima beans, cucumbers, muskmelons, watermelons, squashes, pumpkins, okra, tomatoes, peppers.

(5) Plant about June 1: eggplant, sweet potatoes.

Since Illinois extends a long distance north and south, there is considerable difference in the advancement of the season in different parts of the state. The dates specified above apply to an average season in central Illinois. Under normal conditions planting would take place approximately two weeks earlier for the extreme southern part of the state, and two weeks later for the extreme northern part.

The dates given have reference to the first or earliest planting of the respective crops. In the case of some of the crops mentioned, later plantings may also be made for the sake of securing a succession. This is especially desirable with vegetables that have a short period of edibility, such as radishes, peas, string beans, and sweet corn. Successive plantings may also be made of beets, carrots, and kale if desired. On the other hand, it is almost useless to plant spinach, mustard, garden cress, early turnips, or leaf lettuce after the proper time for the earliest planting is past, even tho these crops remain edible only a short period of time; for later spring plantings usually result in crops deficient in both quality and quantity. To be satisfactory, these crops must complete their development before hot weather arrives; and to be sure of their doing this, they must be planted at the earliest date it is possible to work the soil.

If then, we are to have a satisfactory garden this year, and do our part in contributing to the world's food supply by furnishing our own tables with fresh, succulent vegetables thruout the season, we must not merely plant; we must plant intelligently, and place each kind of seed in the ground at the particular time that will give it the best chance to produce a maximum crop in point of both quantity and quality. The temperature requirements of each kind of vegetable must be known, and the planting timed accordingly.

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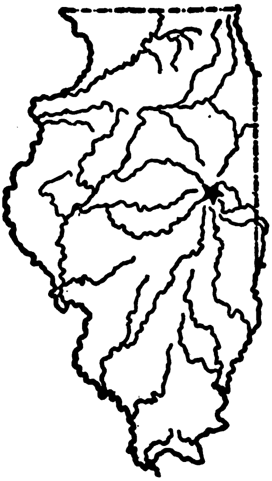
UNIVERSITY OF ILLINOIS
Agricultural Experiment Station

BULLETIN No. 218

THE PRUNING OF WINTER-INJURED PEACH TREES

By A. J. GUNDERSON



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SUMMARY OF BULLETIN NO. 218

INTRODUCTION.—Unusually low temperatures of the winter of 1917-18 caused serious injury to peach trees in southern Illinois, and peach growers were at a loss to know how their trees should be treated, especially with reference to pruning. Page 383

EFFECTS OF WINTER INJURY.—Trees which had been planted one year showed less injury than older trees. The injury included the killing of fruit buds and injury to trunks and branches. Little root injury was observed. Discoloration of the inner wood varying from light to dark brown was the principal internal symptom. Page 383

FACTORS AFFECTING SEVERITY OF INJURY.—Trees devitalized by borers, gummosis, and starvation suffered serious winter injury. Those located in the lower parts of the orchards showed more injury than those on higher parts. Page 385

VARIETIES INJURED.—Observations of Hale trees showed more serious wood injury among them than among Elbertas. Page 385

EXPERIMENTAL PROJECT.—Experimental work was confined to Elbertas. On three-, four-, and five-year-old trees, moderate pruning gave the best results from the standpoint of size, shape, and openness of the trees and in the number of vigorous fruit buds formed on strong wood. Dehorning trees of these ages proved a poor practice. It reduced the size of the trees and in the case of the five-year-old Elbertas in the Voris orchard, killed the trees. No pruning at all gave better results than the dehorning of three-, four-, and five-year-old Elbertas. Waxing the cut surface of dehorned trees was of no value. Nitrate of soda applied at the rate of one pound per tree increased the amount and color of the foliage on moderately pruned four-year-old Elbertas and on check trees, but was of little value on dehorned trees of this age and variety. Page 386

Discoloration of the inner wood is not an absolute indication of the inability of trees to recover from the effects of winter injury. In the orchards studied, in most cases in which discoloration had resulted from the winter injury of 1917-18, new sapwood was observed the following November. The heartwood and pith of trunks and branches showed a ''punky'' or decomposed condition. Page 394

THE PRUNING OF WINTER-INJURED PEACH TREES

By A. J. GUNDERSON, Associate in Horticulture

INTRODUCTION

Unusual and prolonged periods of low temperature in southern Illinois during the winter of 1917–18 resulted in serious injury to peach trees. The month of December, 1917, was the most severe month in the climatological history of the state. In many peach-growing localities of southern Illinois the temperature reached as low as -20° and -25° Fahrenheit. During the periods of low temperature strong winds prevailed. Fortunately, however, there was a good covering of snow in most peach orchards, and therefore the injury was confined to the trunks and the branches of the trees.

Peach growers were at a loss to know how their trees should be treated, especially with reference to pruning. Some were pruning their trees severely, while others were pruning moderately. The writer recommended moderate pruning for both old and young peach trees, as experimental evidence had indicated that for winter-injured peach trees more than one year old moderate pruning was better than severe pruning.[1] In the case of June-budded or small yearling trees planted during the fall of 1917, however, it was recommended that the usual cutting back to whips be practiced.

EFFECTS OF WINTER INJURY

Winter injury to peach trees in Illinois during the winter of 1917–18 included the killing of the fruit buds and injury to wood of different ages, varying from a slight injury to the tissues to severe injury and subsequent death of the trees. In most cases trees which had been planted but one year showed less injury than older trees.

Internal Symptoms of Winter Injury

The internal symptoms of winter injury appeared in the form of discoloration of the heartwood and sapwood, varying in color from light to dark brown (Figs. 1 and 2). The cambium layer turned a pale, watery green. The odor of the cell sap was sour, suggesting fermentation. These conditions were present in the trunk and the branches. The roots of the trees in every peach orchard examined remained normal, owing to the protection afforded by the heavy covering of snow (Fig. 3).

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[1] Mass. (Hatch) Agr. Exp. Sta. Rpt. 1905, p. 167.
U. S. Dept. Agr. Bur. Plant Indus. Bul. 51, part III.
N. Y. (Geneva) Agr. Exp. Sta. Bul. 269.

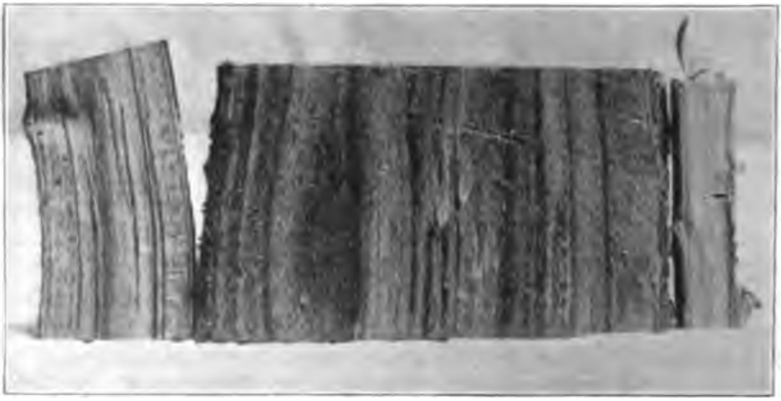

FIG. 1.—LONGITUDINAL SECTION OF BRANCH AND TRUNK OF FIVE-YEAR-OLD ELBERTA

Note the discoloration of the wood of the trunk in comparison with the healthy uninjured wood of the small branch at the right.

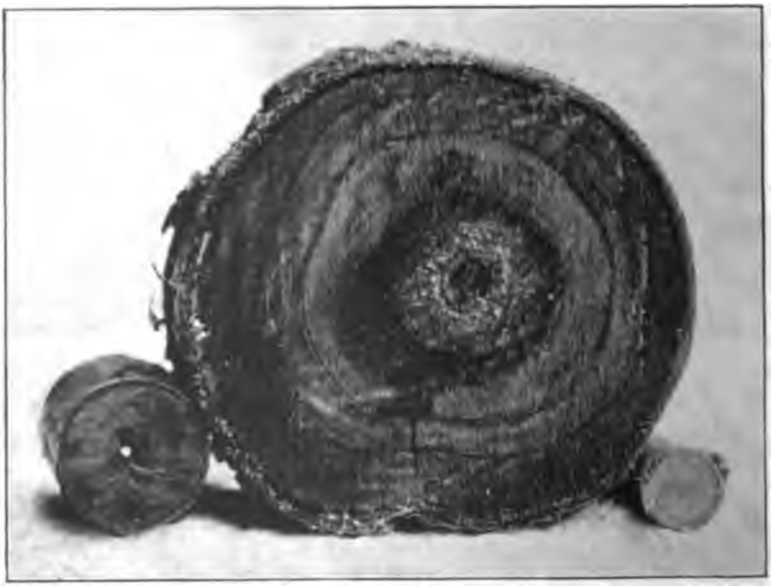

FIG. 2.—CROSS-SECTION OF BRANCH AND TRUNK OF FIVE-YEAR-OLD ELBERTA

Note the discoloration of the wood of the trunk in comparison with the healthy, uninjured wood of the small branch at the right.

External Symptoms of Winter Injury

The first external symptoms of winter injury appeared in the form of shrunken bark on which the lenticles stood out prominently, giving the bark a slightly roughened appearance; and also in some cracking or splitting of the tree trunks. A later symptom was noted in which the leaf buds expanded, owing to the local supply of stored food, but finally wilted on account of the inability of the injured tissues to conduct sap from the roots. This type of injury appeared both on single branches and on entire trees.

FACTORS AFFECTING SEVERITY OF INJURY

The amount of winter injury to peach orchards in southern Illinois varied not so much with latitude, for the low temperatures were quite uniform, as with differences in vigor and healthiness of the trees, elevation of the orchard, and age of the trees. Trees devitalized as the result of previous injury from borers, gummosis, and lack of proper feeding and cultivation were most severely injured and in many cases died. Those located on well elevated and properly drained soil showed less serious injury than those situated on level land or in "pockets." In some cases a difference of a few feet in elevation within the same orchard caused a marked difference in the severity of the injury. Trees which had been planted one year appeared to be injured less than older trees.

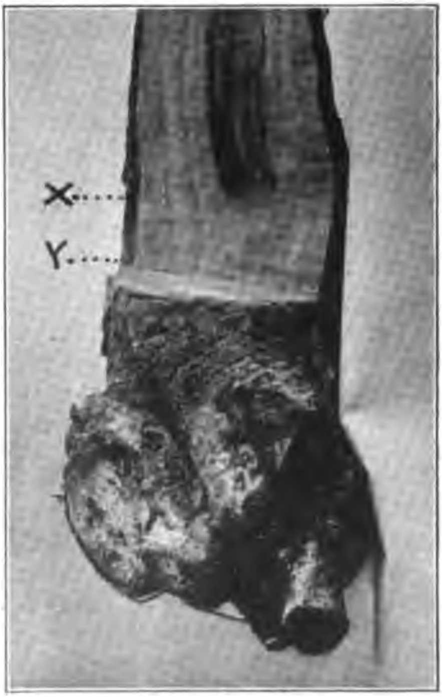

Fig. 3.—Horizontal Section of Elberta Tree

Note the discoloration of wood beginning at the snow-line (X) as compared with the uninjured wood at Y, below the snow-line.

VARIETIES INJURED

Little opportunity was afforded to study winter injury on any variety of peach trees other than Elberta and Hale. The former variety is the most important one grown commercially in southern Illinois, while the latter is being planted to some extent. It has been thought by certain peach growers of other states that Hale is more resistant to low temperatures in the bud than is Elberta, but in southern Illinois, during the winter of 1917–18, both varieties proved failures in this particular. Hale is a less thrifty grower than is Elberta in this section of the state and following the winter of 1917–18 showed as much, and in certain cases more, serious wood injury.

EXPERIMENTAL PROJECTS

As serious winter injury to the wood of peach trees rarely occurs in southern Illinois, advantage was taken of the opportunity offered at this time to conduct investigations with the view of determining a satisfactory way of handling such trees. Experimental work was confined to the Elberta variety.

VORIS ORCHARD, NEOGA, CUMBERLAND COUNTY

In the spring of 1918, the entire Voris peach orchard at Neoga showed serious winter injury, with some dead trees in the lowest parts. The trees were five-year-old Elbertas which had, up to that time, received fairly good care. They stood on level to undulating gray silt loam soil.

Four rows of trees containing seven in each row were selected and pruned as follows on March 28, when the leaf buds had started:

Row 1. One-half of the previous year's wood was removed.
Row 2. Dehorned to within eighteen inches to two feet of the trunks, the one-, two-, and three-year-old wood being removed. Three trees were waxed at the cut surfaces and four left unwaxed.
Row 3. Check. Unpruned.
Row 4. From four trees all the previous year's wood was removed. Three trees were pruned leaving four inches of the previous year's wood.

Judging from the discoloration of the wood of all the trees in this experiment, the injury was very severe. In Row 2 the wounds of three of the trees were waxed immediately after dehorning, while four trees were left unwaxed with the view of determining whether or not the checking of evaporation would aid recovery.

On July 23, observations were made upon the relative condition of the trees. The trees in Rows 1 and 4 were the best from the standpoint of growth and amount and color of the foliage. The check or unpruned trees were making a straggling growth and presented an unthrifty appearance. All the trees in Row 2, which had been dehorned, were practically dead, with the exception of one unwaxed tree. It may be concluded, therefore, that evaporation at the cut surfaces of the dehorned trees was not directly responsible for their death. The dehorning of these trees resulted in an extreme reduction in the amount of leaf surface with a corresponding reduction in amount of transpiration. As it is quite probable that transpiration in peach trees exerts some effect upon the flow of sap, it seems likely that the trees of Row 2 did not draw a sufficient amount of sap from their roots to sustain them and permit growth. Then, too, the season was extremely hot and dry.

On October 29, observations were again made to ascertain the condition of the trees in the different rows. In Row 2 only one tree remained alive, one which had been left unwaxed. It had made the usual heavy growth characteristic of dehorned peach trees and carried practically no fruit buds. The trees in Rows 1 and 4 had an abundance of fruit buds present on strong wood. The unpruned trees in Row 3 showed plenty of fruit buds, but they were borne on small, weak branches.

POFF ORCHARD, OLNEY, RICHLAND COUNTY

The Poff peach orchard at Olney showed a variable degree of winter injury following the winter of 1917–18. That part of the orchard well elevated and properly drained consisted of four-year-old Elbertas. The rest of the trees, situated on more level and lower ground, were three-year-old Elbertas, which seemed to show slightly more serious injury than the four-year-old trees on the higher ground. The soil of this orchard is yellow gray silt loam.

Series 1: Three-Year-Old Elbertas

Four rows containing five three-year-old Elberta trees each were pruned in the following manner on March 26, when the leaf buds were out:

Row 1. Pruned moderately; previous year's growth clipped approximately one-half.
Row 2. Dehorned, the one- and two-year-old wood removed.
Row 3. One-year-old wood removed.
Row 4. Check. Unpruned.

On May 12, the trees of Rows 1 and 3 were making the best growth and carrying the best colored foliage. The trees in Row 2, which had been dehorned, were growing slowly but had good foliage. The unpruned trees were making the poorest growth and carried sickly, yellow leaves.

On July 9, the trees in Row 3, from which all of the previous year's wood had been removed, had made the greatest amount of growth, while the trees in Row 1, the one-year-old wood of which had been clipped, were second, with the trees in Row 2, which had been dehorned, and those of Row 4, which had been left unpruned, following in amount of growth. Trees which had been dehorned were very dense and were reduced so low that much of the growth lay on the ground, and was therefore useless so far as its ability to carry

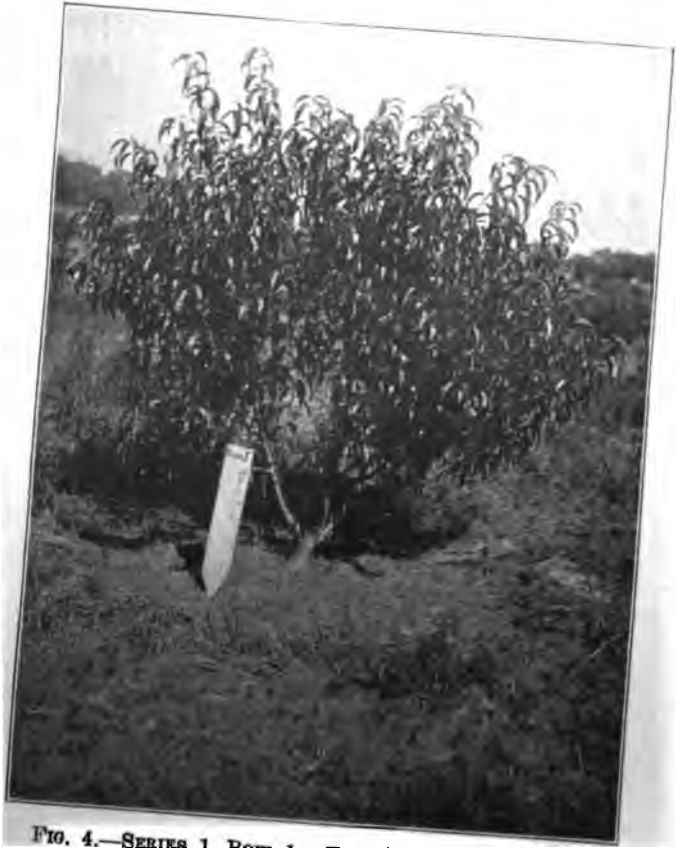

FIG. 4.—SERIES 1, ROW 1: THREE-YEAR-OLD ELBERTA
Pruned moderately. Previous year's wood clipped.

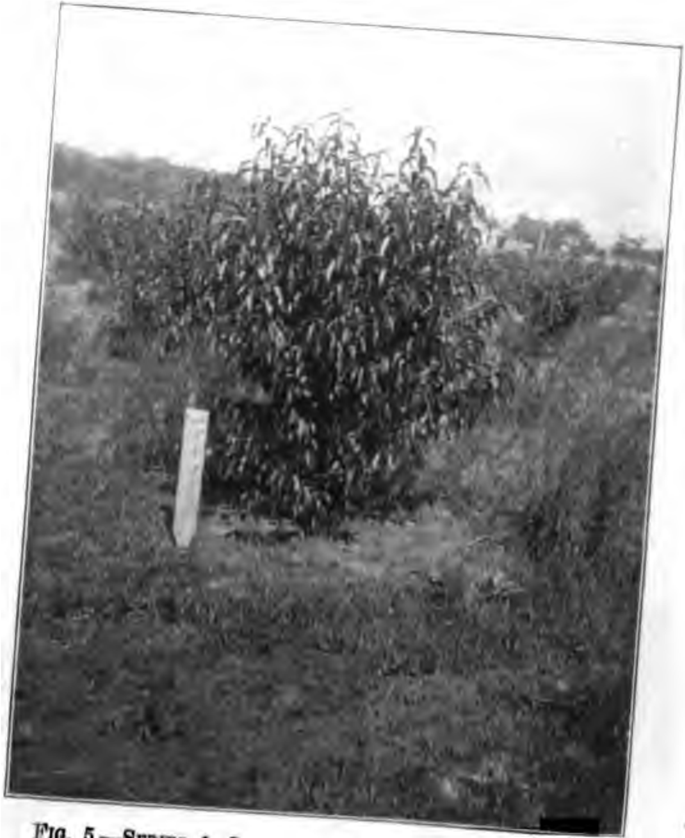

FIG. 5.—SERIES 1, ROW 2: THREE-YEAR-OLD ELBERTA
Dehorned, one- and two-year-old wood removed.

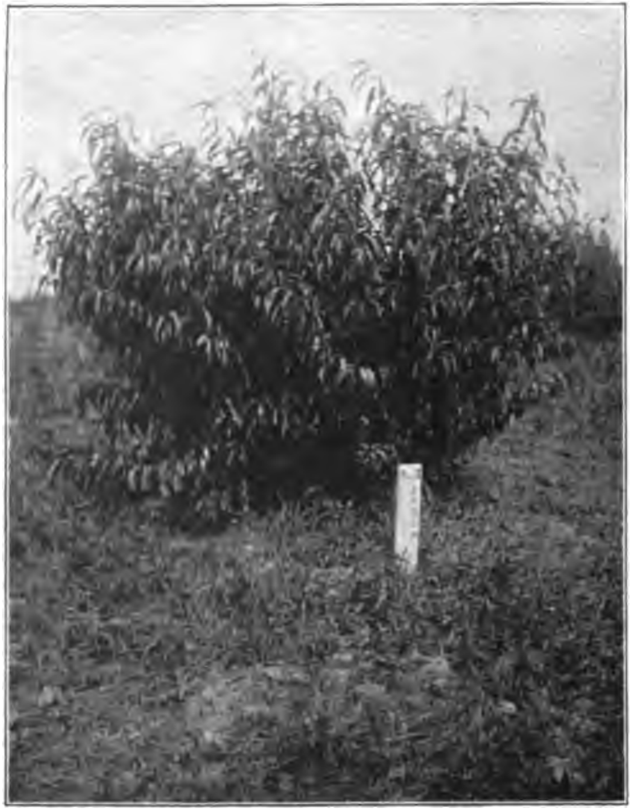

FIG. 6.—SERIES 1, ROW 3: THREE-YEAR-OLD ELBERTA
One-year-old wood removed.

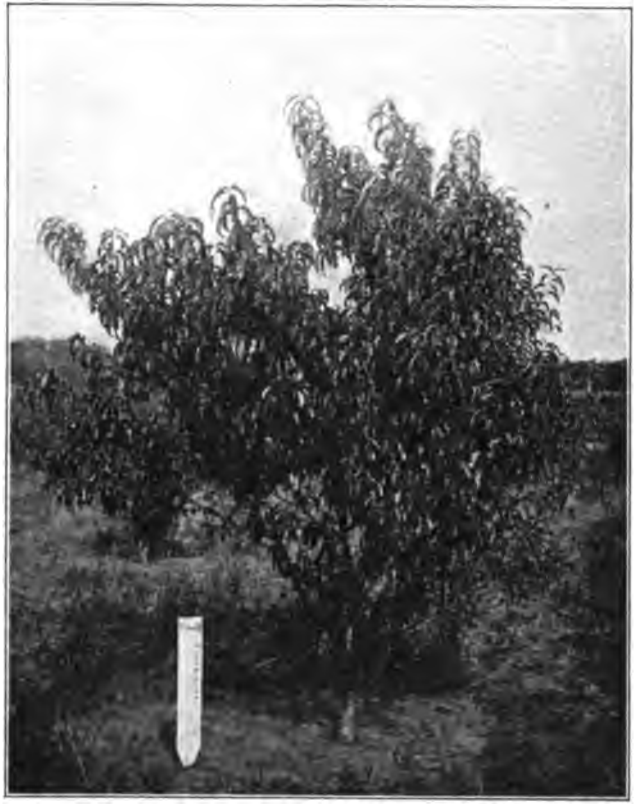

FIG. 7.—SERIES 1, ROW 4: THREE-YEAR-OLD ELBERTA
Check. Unpruned.

fruit-bearing wood in the future was concerned. In Figs. 4 to 7 one tree from each of the four rows is shown.

On October 30, when most of the leaves had fallen, observations were made to determine the relative amounts of fruit-bud formation on the trees of the different rows. The greatest number of fruit buds had developed in Row 1, the trees whose one-year-old wood had been clipped; the next greatest number was on the trees in Row 4, which had not been pruned, while a smaller number of buds was present on the trees in Row 3, from which the one-year-old wood had been removed. Row 2, the trees of which had been dehorned, developed practically no fruit buds, owing to the very heavy primary growth that resulted from the severe pruning.

The fruit buds on the trees of Rows 1 and 3, which had been moderately pruned, were carried on strong growth, while those on the unpruned trees in Row 4 developed on small, weak branches.

Series 2: Four-Year-Old Elbertas

Five rows of trees, each containing five four-year-old Elbertas, were pruned in the following manner on March 26, when the leaf buds were out:

Row 1. Pruned moderately, previous year's growth clipped approximately one-half.
Row 2. Dehorned, the one-, two-, and three-year-old wood removed.
Row 3. One-year-old wood removed.
Row 4. Dehorned, the one- and two-year-old wood removed.
Row 5. Check. Unpruned.

On April 1, one pound of nitrate of soda was applied broadcast to three trees in each row for the purpose of studying the effects of this fertilizer on the recovery of the trees from winter injury.

On May 12, the trees in Rows 1 and 3 were making a better type of growth than those in Rows 2 and 4. The unpruned trees in Row 5 were making weaker growth at this time.

The foliage of the trees which had received the nitrate of soda was heavier and of a darker green color than that of the untreated trees. This difference was much more apparent, however, in the check and the moderately pruned trees than in those dehorned. This was probably due to the fact that heavy pruning of peach trees usually results of itself in the stimulation of a heavy growth of wood and foliage, especially when the trees are in vigorous condition.

On July 9, the rankest growth had been made by the trees in Rows 2 and 4. The tops were very dense and were reduced so low that many of the branches lay on the ground, making it necessary to remove them later. The trees which were making the most desirable growth from the standpoint of amount and spread were those in Row

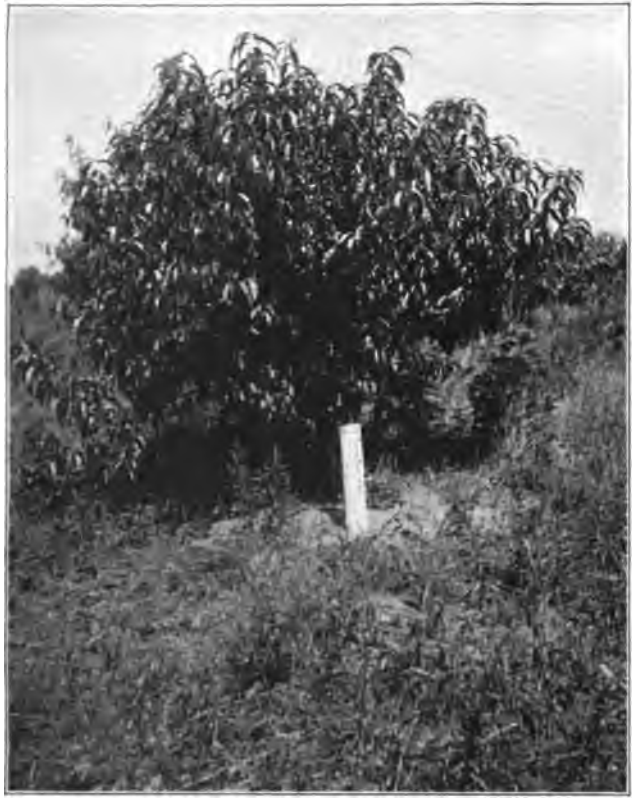

FIG. 8.—SERIES 2, ROW 1: FOUR-YEAR-OLD ELBERTA
Pruned moderately. Previous year's wood clipped.

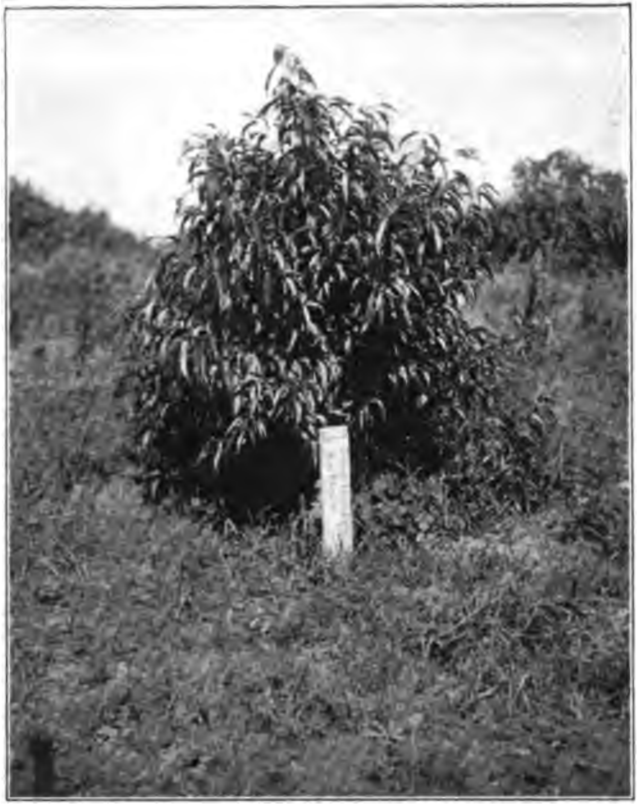

FIG. 9.—SERIES 2, ROW 2: FOUR-YEAR-OLD ELBERTA
Dehorned, one-, two-, and three-year-old wood removed.

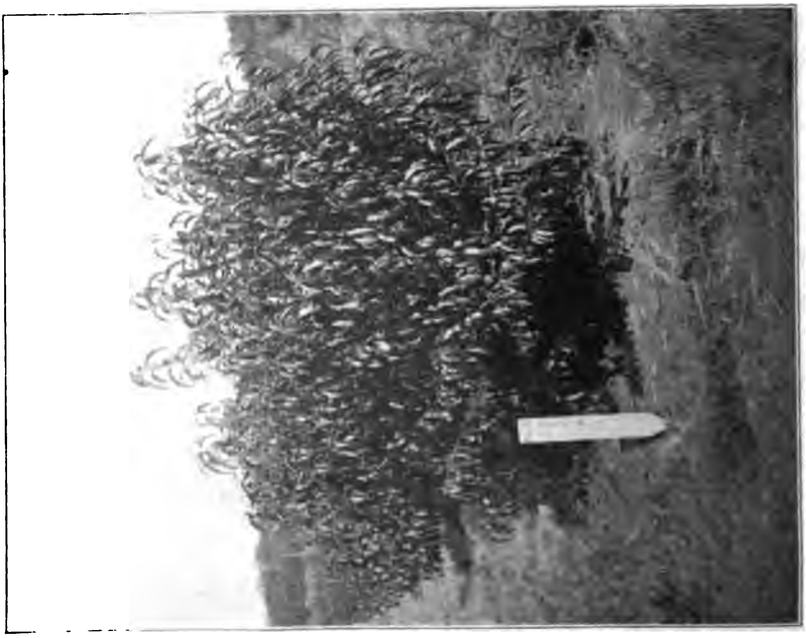

FIG. 10.—SERIES 2, ROW 3: FOUR-YEAR-OLD ELBERTA
One-year-old wood removed.

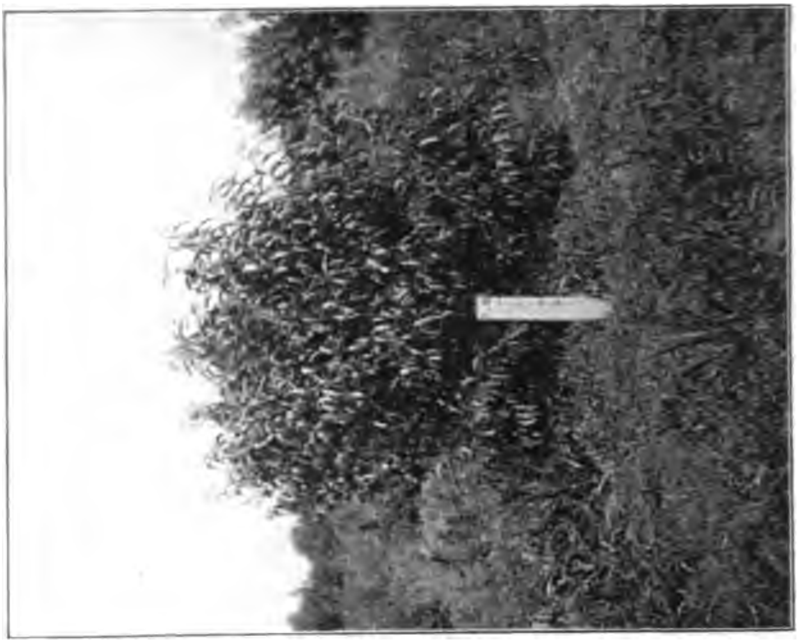

FIG. 11.—SERIES 2, ROW 4: FOUR-YEAR-OLD ELBERTA
Dehorned, one- and two-year-old- wood removed.

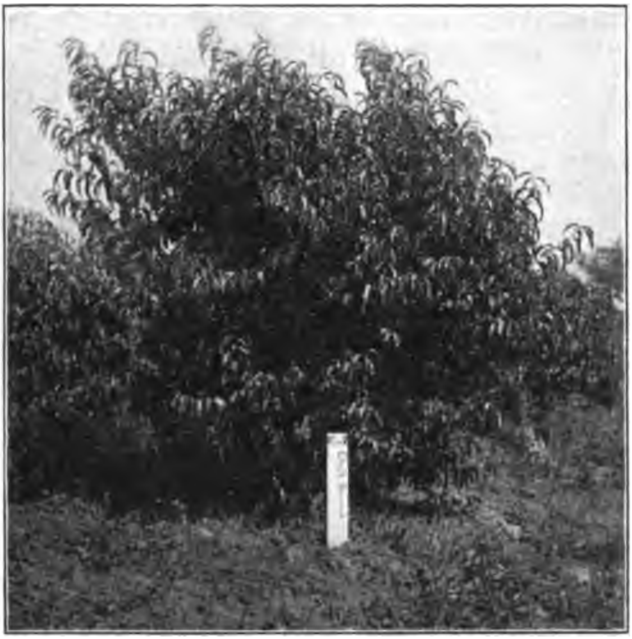

FIG. 12.—SERIES 2, ROW 5: FOUR-YEAR-OLD ELBERTA Check. Unpruned.

1, whose one-year-old wood had been clipped one half. The next best trees were those in Row 3, from which the one-year-old wood had been entirely removed. The unpruned trees were better than those dehorned, from the standpoint of both size and shape.

The effects of the nitrate of soda were still noticeable on the check trees and on the trees which had been moderately pruned.

Observations were made October 30 on the relative amount of fruit-bud formation on the trees in the different rows. The trees in Row 1, whose one-year-old wood had been clipped, carried the largest number of well distributed, vigorous fruit buds and on wood of desirable size. The unpruned trees carried a large number of less plump but well distributed fruit buds on small-sized branches. The trees in Row 3, from which the one-year-old wood had been removed entirely, had a good many poorly distributed fruit buds carried on wood that was a little too heavy to be desirable. The tops of the trees in this row were so dense as to require considerable thinning of the branches and consequent removal of many fruit buds.

Very few fruit buds were present on the dehorned trees in Rows 2 and 4. This was due to the fact that, as usual on severely pruned trees, long and heavy primary growth of branches developed, on which relatively few fruit buds ever appear.

INTERNAL APPEARANCE OF WOOD TISSUES AT THE END OF THE GROWING SEASON

Examination of the internal tissues of the wood of both branches and trunks was made in both experimental orchards during November after the growing season had ended. It was observed that a new layer of sapwood had been formed, of greater thickness in the trunks of the trees than in the branches (Fig. 13). The heartwood and pith had assumed a "punky" condition, suggesting decomposition. Whether such a condition will eventually prove detrimental to the productiveness and vigor of the trees remains to be seen.

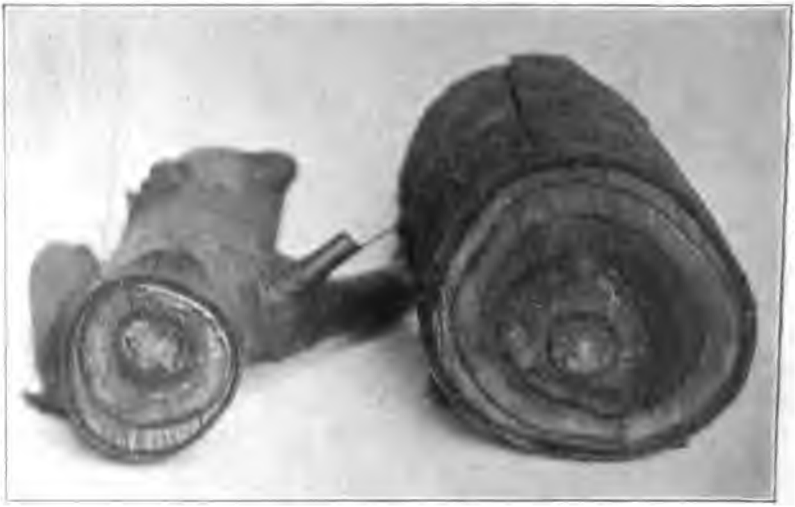

FIG. 13.—CROSS-SECTION OF BRANCH AND TRUNK OF THREE-YEAR-OLD ELBERTA MADE ON NOVEMBER 15, 1918

Note the "punky" condition of the pith and heartwood; also the new ring of sapwood formed around the injured tissues.

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